PUBLIC INTEREST ENERGY RESEARCH PROGRAM

Renewable Energy:
BIOMASS RD&D PLAN

1999-2011

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I. Description of Biomass Energy Technologies

A. Biomass as an Energy Resource

Biomass energy is an indirect solar energy and it is the oldest known renewable energy that humans have been using since the discovery of fire. The term biomass refers to vegetative and organic materials coming from agricultural, forestry, urban, and other rural activities, mainly *via* photosynthetic process capturing some of the solar energy. Biomass energy is otherwise called energy contained in the plants and organic matter. Historically, biomass has supplied food, feed, fiber, and structural materials needs for humans through metabolism of biological organisms–and, over million of years of geologic time, to form fossil fuels like oil, natural gas, and coal. By category, biomass includes agricultural residues, forest slash and thinning, urban wood wastes, yard wastes, food processing wastes, livestock manure, chaparral, lumber mill waste, municipal solid wastes, and other residues derived therefrom.

The potential biomass resources in the United States (U.S.) is estimated at 55 quads (1 quad = 10^{15} Btu) or over 3 billion bone dry tons (BDT) (1). Only 14 quads of biomass resources are estimated to be available and the whole U.S. is currently using 3 quads (total U.S. consumption from all energy sources is 84 quads). Various forms of biomass energy (including generating electricity, heating homes, and fueling vehicles and providing process heat for industrial facilities) account for nearly 4 percent of energy consumed and 45% of renewable energy used. The contribution of biomass power generation is second only to that of hydropower among renewables to the national energy supply. Currently, independent biomass power generators in the whole U.S. supply 11 billion kWh/yr to the national electricity grid (1).

The potential of biomass resources to supply much larger amounts of useful energy with reduced environmental impacts compared to fossil fuels has stimulated substantial research and development of systems to grow, harvest, handle, process, store and convert biomass to electricity, heat, liquid and gaseous fuels, and other chemicals and products. However, the key to accessing the energy content in biomass is converting the raw biomass materials (otherwise called feedstock) into a usable form, which can be accomplished through three principal routes: 1) thermochemical (combustion and gasification), 2) biochemical (*via* anaerobic digestion and fermentation), and 3) physicochemical (mechanical and chemical extractions). The first two energy conversion routes are commonly used, and in practice, combinations of two or more of these routes may be used in the generation of final product or products.

There are economic, environmental, and societal advantages from the development of biomass energy conversion technologies. The opportunity is clear. However, it requires forward-thinking vision, integration of stakeholders, investment in new approaches for RD&D, and coordination of RD&D to generate a secure and sustainable future for the biomass-based industry.

B. Biomass Energy Conversion Technologies

The brief descriptions of thermochemical and biochemical energy conversion routes for biomass are shown below.

1. Thermochemical Biomass Energy Conversion

Thermochemical biomass energy conversion could be classified as direct combustion and partial combustion or otherwise known as gasification.

Simply, the thermochemical conversion pathways of biomass can be represented as follows:

Combustion:

$$C_xH_yO_z + n_1H_2O + n_2(1+e)(O_2+3.76N_2) = n_3CO_2 + n_4H_20 + n_5N_2 + n_6O_2$$

Gasification:

$$C_xH_yO_z + n_1H_2O + n_2(1+e)(O_2+3.76N_2) = n_3CO_2 + n_4H_20 + n_5N_2 + n_6O_2 + n_7CO + n_8H_2 + n_9CH_4 + n_{10}C(s) + \text{other gases} + \text{tars}$$

where:

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$n_1 - n_{10}$: are stoichiometric coefficients and are dependent on the concentration of carbon, hydrogen and oxygen of biomass fuel expressed in $C_xH_yO_z$ (moisture free and ash free basis)

e: amount of excess oxygen

Air is approximated in the normal engineering fashion as consisting of 21% by volume oxygen and 79% equivalent nitrogen.

These thermochemical energy conversion pathways are described as follows:

a. Biomass Direct Combustion

Historically, biomass to electricity industry has used direct combustion-steam boiler and steam turbine technologies to generate electricity from biomass resources. Biomass direct combustion involves the oxidation reaction of biomass with excess air, producing hot flue gases and consequently producing steam. Biomass direct combustion for power generation uses the Rankine or Steam Cycle Technology as illustrated in Figure 1.

The two common biomass direct combustion (or simply boiler) configurations used for steam generations are stoker (stationary- and travelling-grate) and fluidized bed combustors. These technologies are commonly being used for baseload applications.

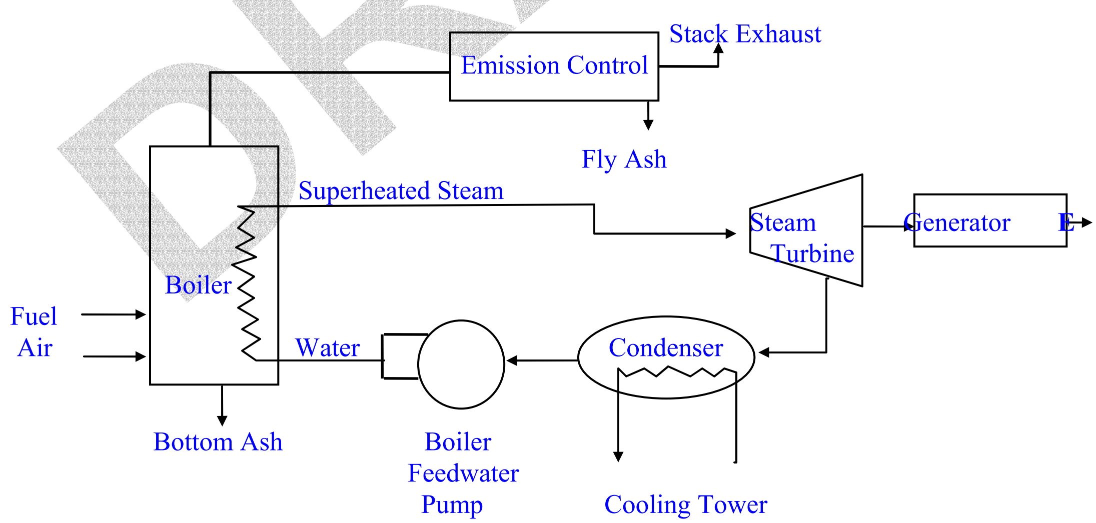

Figure 1. Rankine Cycle Power Plant

All biomass combustion systems require feedstock storage and handling systems. Biomass fuel is burned in a boiler, which consists of a combustor with one or more heat exchangers to make steam. Typical medium efficiency units utilize steam temperatures

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and pressures of approximately 500ºC and 6MPa. The steam is expanded through a turbine that drives an electrical generator. The steam from the turbine exhaust is condensed, and the water re-circulated to the boiler. Combustion products exit the combustor, are cleaned, and vented to the atmosphere. Typical cleaning devices include wet or dry scrubbers for sulfur and chloride control, cyclones, baghouses, or electrostatic precipitators for particulate matter removal and for selective or non-selective catalytic reduction of NOx. Low CO and hydrocarbon emissions are maintained by proper control of air-fuel ratio in the furnace and boiler. Power boilers utilize multiple heat exchangers in manufacturing steam. Water returns to the boiler from the condenser by means of feedwater pumps.

To-date, this direct combustion technology is commercially available, and is the main biomass technology used in California. Biomass direct combustion technologies have relatively low thermal efficiencies typically on the order of 17% to 23%. This is about half the efficiency of natural gas-fueled combined cycle facilities (40-45%).

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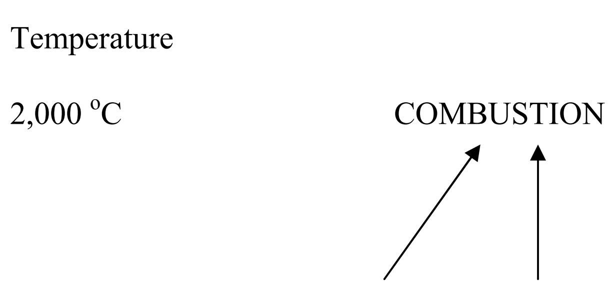
b. Biomass Gasification

The conversion of biomass to a low- or medium-heating-value producer gas *via* thermal gasification generally involves two processes, namely, pyrolysis and gasification *per se*. Pyrolysis, releases the volatile components of the fuel at temperatures below 600^{o}C (1112^{o}F) via set of complex reactions. The other products in addition to volatile vapors are hydrocarbon gases, hydrogen, carbon monoxide, carbon dioxide, tars and water vapor. Biomass fuels tend to have more volatile components (70-86% on a dry basis) than coal (30%), pyrolysis plays a proportionally larger role in biomass gasification than coal gasification. The by-products of pyrolysis that are not vaporized are referred to as char, consisting mainly of fixed carbon and ash. In the gasification process, char conversion, the carbon remaining after pyrolysis undergoes the classic gasification reaction (i.e. steam + carbon) and/or combustion (carbon + oxygen). Figure 2 shows the schematic of gasification/combustion process. The combustion reaction provides the heat energy required to drive the pyrolysis and char gasification reactions. Due to its high reactivity (as compared to coal and other solid fuels), all of the biomass fuel, including char, is normally converted to gasification products in a single pass in a gasifier system.



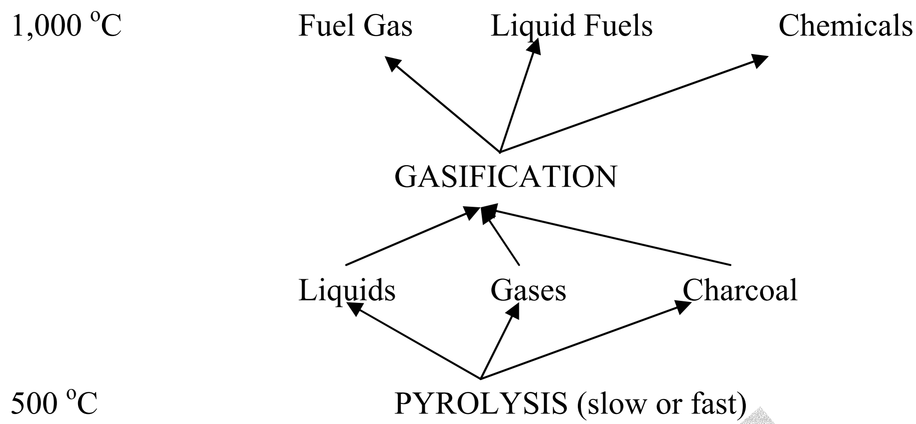


Figure 2. Schematic of Gasification/Combustion Process

Gasification technologies available for biomass are broadly grouped into the following:

1) *Fixed bed (moving packed bed)*
    1) Updraft (counter flow)
    2) Down draft (co-flow)
    3) Cross draft
2) *Fluidized bed (single solid, multi-solid, directly heated, indirectly heated)*
    1) Atmospheric
    2) Pressurized
    3) Circulating
    4) Bubbling
3) *Entrained bed*
4) *Tumbling bed*
5) *Stirred bed*

In advanced and high efficiency gasification power systems, biomass feedstocks are converted to gas, which is then fed through industrial or gas turbines (aero-derivatives and microturbines).

Small biomass-fueled gasifiers are also available from a number of manufacturers. These units are mainly used for closed-coupled applications such as firing the gas in kilns, boilers, or small motive power engines. Small-scale biomass gasification facilities have been working in many developing countries such as Philippines, Africa, Brazil, India and other places.

Put at its minimum of complexity, a gasifier works by the partial oxidation of the original fuel. Under this process, the carbon reacts with limited oxygen to produce carbon monoxide, while at the same time it also reacts with water to produce hydrogen and additional carbon monoxide. This combination of H_2 and CO is the key component of the "syngas." In most processes, the content of the syngas will be at least 80% hydrogen and carbon monoxide.

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Due to the potential of high thermal efficiency, integrated gasification combined cycle (IGCC) technology is under development in the US and Europe for biomass in large-scale facilities. Work is being done in this technology incorporating fluidized bed gasification, combustion turbine and steam turbine combined cycles, and ceramic filter hot gas clean up to protect the combustion turbine from alkali deposits and corrosion.

2. Biochemical Energy Conversion of Biomass

Biochemical energy conversion pathways described here includes anaerobic digestion and landfill gas to energy recovery systems and biomass to ethanol fermentation.

a. Biomass Anaerobic Digestion and Landfill Gas to Energy (LFGTE) Recovery System

Anaerobic digestion is a microbial biological gasification process of biomass and other organic waste which produces biogas (or digester gas), a gaseous fuel consisting of methane (50% to 80%) and carbon dioxide (15% to 45%) and 5% water, with small concentration of H_2S and leaves a stabilized residue. It is essentially fermentation of biomass by anaerobic bacteria.

The overall complete reaction model for anaerobic digestion of the organic portion of biomass is

$$C_xH_yO_z + (x - y/4 - z/2)H_2O = (x/2 - y/8 + z/4)CO_2 + (x/2 + y/8 - z/4)CH_4$$

In general, three groups of microorganisms are at play. First group is the hydrolyzing bacteria that convert complex organic material into soluble compounds. Second group is acid forming (acetogenic) bacteria that convert soluble compounds into low molecular weight organic acids. These acids are then converted into methane and carbon dioxide by methane forming (methanogenic) bacteria. For the digestion of soluble or easily biodegradable materials (such as livestock manure), the methane forming step is slower and is thus the rate determining step. For other biomass materials (such as cellulosic materials), however, the first fermentation steps, hydrolysis and acidification, can become the limiting steps. Temperature affects the rate of digestion and should be maintained in the mesophilic range (95º F to 105ºF) with an optimum of 100ºF. It is possible to operate in the thermophilic range (135ºF to 145ºF), but the digestion process is subject to upset if not closely monitored.

An anaerobic digester is an engineered containment vessel designed to promote the growth of anaerobic bacteria. There are seven types of reactors used for anaerobic digestion: covered lagoon, plug flow, complete mix, packed bed reactor, anaerobic sequencing batch reactor (ASBR), upflow anaerobic sludge blanket (UASB), and high solids reactor. These digesters can be employed using high moisture biomass feedstock such as livestock manure, food processing waste, wastewater, sludge and other municipal solid waste.

Landfill gas to energy (LFGTE) recovery system is basically anaerobic digestion of municipal solid wastes (MSW), otherwise known as garbage, that are disposed in landfills. Landfilling serves as the predominant waste management facilities in California and the US. The organic portions of the MSW in landfill, including paper and paperboard, yard wastes, and food wastes, are decomposed through biochemical reactions mentioned above where anaerobic condition exists. Landfill gas is produced as a result of anaerobic decomposition of organic wastes. In general, landfill gas contains 50% of methane (CH_4), 45% of carbon dioxide (CO_2), and other traces of gas such as nitrogen (N_2), oxygen (O_2), hydrogen sulfite (H_2S), and water vapor (2).

b. Biomass Fermentation to Ethanol

Ethanol is a simple two carbon alcohol, with the chemical formula, $\mathbf{CH_3CH_2OH}$, that can be produced by chemical synthesis by direct hydration of ethylene (ethylene derived from petroleum), or produced by biomass fermentation using microorganisms. Production of ethanol has been limited to using sources of soluble sugar or starch, primarily in the Midwest, U.S. using corn. Ethanol production grew from 175 million gallons in 1980 to 1.4 billion gallons in 1998, with support from Federal and state ethanol tax subsidies and the mandated use of high-oxygen gasoline. Currently, over 1.5 billion gallons of ethanol is produced in the US. California ethanol production is limited, a modest amount of 6 million gallons per year from food processing wastes and other liquid products, such as cheese whey. Demand for ethanol could increase further if methyl tertiary butyl ether (MTBE) is eliminated from gasoline. In March 1999, Governor Gray Davis announced the phase out of the use of MTBE in gasoline by 2002 in California, which uses 25 percent of the global production of MTBE. It is unclear, however, whether the U.S. Congress will eliminate the minimum oxygen requirement in reformulated gasoline (RFG), an action that would reduce the need for ethanol. If the oxygen requirement is eliminated, ethanol will still be as valuable as an octane booster and could make up some of the lost MTBE volume.

Extending the volume of conventional gasoline is a significant end use for ethanol, as is its use as an oxygenate. To succeed in these markets, the cost of ethanol must be close to the wholesale price of gasoline, currently made possible by the Federal ethanol subsidy. However, the subsidy is due to expire in 2007, and although the incentive has been extended in the past, in order for ethanol to compete on its own merits the cost of producing it must be reduced substantially.

The production of ethanol from corn is a mature technology that is not likely to see significant reduction in production costs. Substantial reductions must be possible, however, if lignocellulosic-based feedstocks are used instead of corn. The ability to produce ethanol from biomass will be key to making ethanol competitive with gasoline. In addition, if an ethanol production system were co-located with biomass power plant

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certain synergies could occur. In particular, lignin from the ethanol plant could be utilized by the power plant, while steam and electricity from the power plant could be utilized by the ethanol facility. Also, it is likely that the ethanol plant could utilize other existing utilities at the biomass power plant, such as sewage handling, cooling water and other buildings. It is also likely that the ethanol production facility would make arrangements to procure and manage feedstocks for the ethanol plant and to provide certain operations and maintenance functions for the ethanol plant.

Although lignocellulosic feedstocks are less expensive than corn, today they are more costly to convert to ethanol because of extensive processing required. Currently, the cost of producing ethanol from cellulose is estimated to be between $1.15 and $1.43 per gallon in 1998 dollars, compared to $1.10 per gallon for ethanol produced from corn and today's wholesale price for gasoline of between $.80 and $.90 per gallon. Thus, the system integration of biomass power plants with ethanol production provides economic merits for the biomass industry under the electricity-deregulated environment.

Brief overview of lignocellulosic conversion technologies and various feedstock options are presented below.

Enzymatic hydrolysis; simultaneous saccharification and co-fermentation (SSCF): The steps in the conversion of cellulosic materials to ethanol in processes featuring enzymatic hydrolysis include pretreatment, biological conversion, product recovery, and utilities and waste treatment. SSCF is an adaptation to the process, which combines hydrolysis and fermentation in one vessel. Sugars produced during hydrolysis are immediately fermented into ethanol. By fermenting the sugars as soon as they form, eliminates problems associated with sugar accumulation and enzyme inhibition.

Dilute acid hydrolysis:
This process uses low concentration acids and high temperatures to process the cellulosic biomass. Lignocellulose biomass is pretreated with approximately .5% acid in liquid at up to 200ºC to hydrolyze the hemicellulose and expose the cellulose for hydrolysis. The hemicellulose hydrolysis yields most pentose (C_5) sugars, principally xylose and arabinose, which are fermented to ethanol and distilled. The remaining solids, cellulose and lignin, enter the second stage hydrolyzer where cellulose is converted to glucose with approximately 2% acid in liquid at up to 240º C. The resulting sugars are then fermented to ethanol and distilled.

Concentrated acid hydrolysis:
This process uses high concentration halogen acids and nears ambient temperatures to convert cellulosic biomass to sugars. The decrystalization and hydrolysis of cellulose with nearly 100% yields may be accomplished with 40 wt% hydrochloric acid, 60 wt% sulfuric acid, or 90 wt% hydrofluoric acid. The liquid phase hydrochloric acid process is the only halogen process to have reached commercial development.

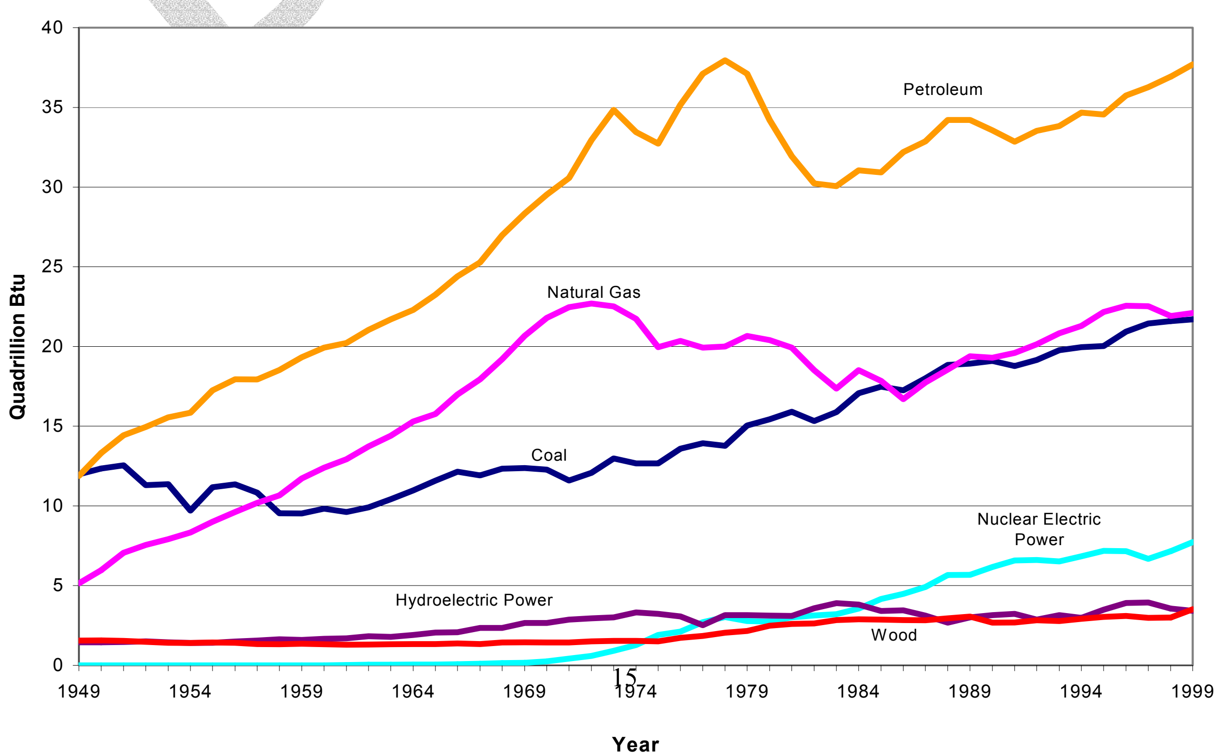
The feedstock is pretreated with approximately 10 wt% acid liquid stream, which is recycled from cellulose hydrolysis. Pretreatment hydrolyzes the hemicellulose into C_5 and C_6 sugars and exposes the cellulose for hydrolysis. The subsequent liquid acid and sugar stream is separated from the solids, neutralized, fermented and distilled. The solids mostly cellulose and lignin, enter the second stage hydrolyzer and are mixed with 40-90 wt% acid (the concentration depends on acid type). Cellulose is converted into C_6 glucose sugars. After another liquid-solid separation step, the liquid containing about 10% acid and 10% glucose is recycled to the hemicellulose hydrolysis / pretreatment vessel. The remaining solids are washed, dried and used as fuel source for power production.

Direct microbial conversion: In this process, enzyme production, hydrolysis and co-fermentation is in a single vessel. The process was described as early as 1933. This process is similar to SSCF except cellulose production occurs within the same vessel as saccharification and co-fermentation. Direct microbial conversion does require a pretreatment step.

Biomass gasification-fermentation: Gasification is the combustion of carbonaceous material, including biomass, under precise fuel to air mixture to control the byproducts. The desired byproducts are CO, CO_2, and H_2, which are fermented anaerobically into ethanol. All of the components of biomass, including hemicellulose and lignin, are converted to ethanol. Biomass/waste is gasified (partial combustion), cooled to near ambient temperatures, and passed through a reactor where the gasses are converted to ethanol by the culture of bacteria maintained within the reactor. The ethanol is removed through a membrane that retains the bacteria culture, subsequently recycling the bacteria.

C. Development and Growth of Biomass Energy

Biomass energy (especially wood energy) in the U.S. has been a significant part of



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energy mix for a very long time (Figures 3 and 4). In fact, fuelwood as biomass was overwhelmingly the dominant energy resource from 1775 until late in the last century (3). In the middle of the 19th century, most Americans lived in the countryside and worked on farms. The country ran mainly by wood fuel and was relatively unimportant in global affairs. A hundred years later, after the U.S. had become the largest producer and consumers of fossil fuels, most Americans were city dwellers and relatively few were agricultural workers.

Figure 3. U.S. Energy Consumption Estimates Year 1949 – 1999 (3)

The U.S. had roughly tripled its per capita consumption of energy and become a global superpower. The modern era is notable for the accelerated development of new sources of energy in the U.S. Coal ended the long dominance of fuelwood in the U.S. in 1885, only itself to be surpassed in 1951 by petroleum and then by natural gas few years later. The curve in Figure 3 also depicted the development hydroelectric power, nuclear and other sources. The most striking is the development of petroleum and natural gas. Although coal, oil and natural gas became the world's most important energy sources; their dominance does not extend to all corners of the globe. In many areas biomass energy remains indispensable and diversity in energy supplies has been the rule.

As depicted in Figure 4, biomass (mainly wood) fuels are used for industrial, commercial, residential, and electricity generation. The largest part of biomass use is for industrial application, heat and steam in the primary wood products industries such pulp and paper and lumber industries. Overall, by counting both electricity and non-electricity uses (such as ethanol fuel for transportation), biomass accounts for about 3.25% of U.S. total energy use, about 3 quadrillion Btu.

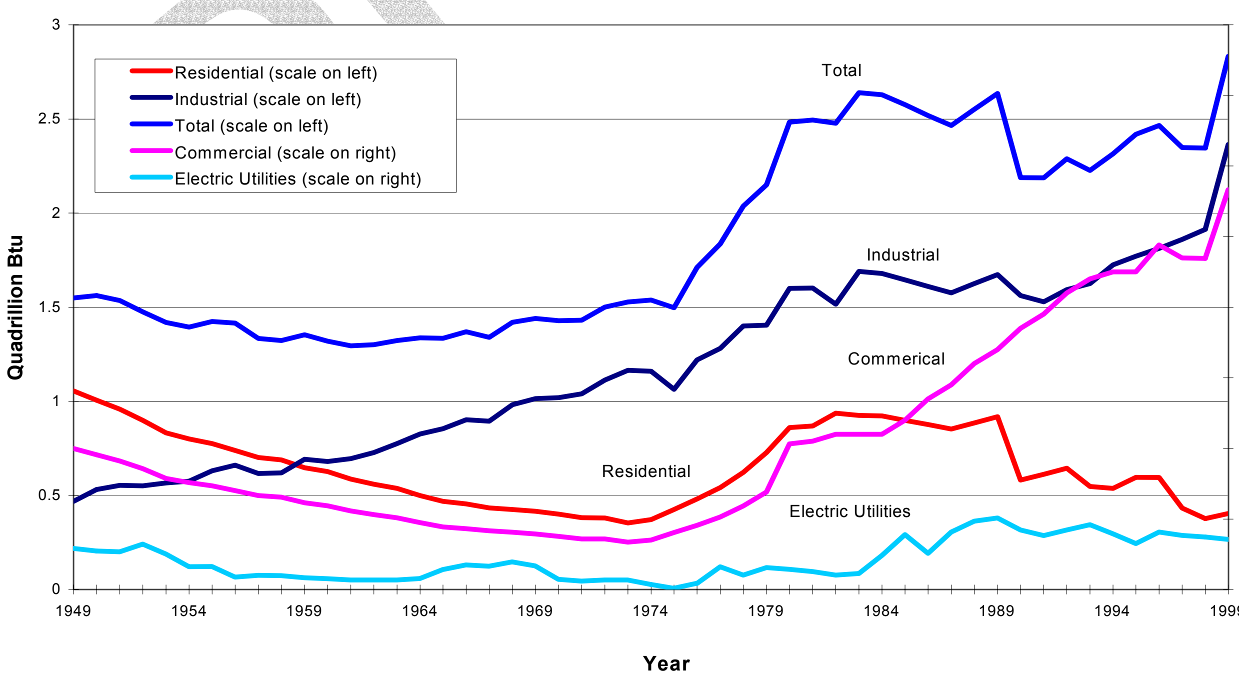

Figure 4. U.S. Biomass Energy (Wood only) Consumption Estimates, 1949-1999 (3)

Biomass energy use in the U.S. grew rapidly in 1980-1990's. The catalyst to this rapid growth was the landmark federal legislation known as the Public Utility Regulatory Policies Act (PURPA, 1978). PURPA and standard offer contracts (special purchase agreements such as Standard Offer contracts in California) provided biomass and other renewable energy technologies a strong market development force for the industry in the state. By mid 1990's, it has grown slowly or not all in the recent years due the loss of the special purchase agreements.

The total electric generating capacity in the U.S. to-date is about 10,300 MW (Table 1). It is expected that biomass energy use may be tripled by 2010 and doubled again by 2030. By 2050, it estimated that biomass power generation could be as high as 125,000 MW (4).

Table 1. U.S. Electric Generating Capacity, 1994-1998 (MW) (3)

Source	**1994**	**1995**	**1996**	**1997**	**1998**
Hydro	78,042	78,563	76,437	79,788	79,573
Geothermal	3,006	2,968	2,893	2,853	2,917
Biomass	**10,468**	**10,283**	**10,560**	**10,538**	**10,269**
Solar/PV	333	333	333	334	365
Wind	1,745	1,731	1,678	1,579	1,698
Total Renewables	**93,594**	**93,877**	**91,900**	**95,093**	**94,822**
Non-Renewables	670,420	675,640	683,972	683,409	681,062
TOTAL	**764,014**	**769,517**	**775,872**	**778,502**	**775,884**

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II. Biomass Energy in California

A. California's Biomass Energy Resources

California generates over 60 million BDT per year of biomass, which is a growing waste disposal problem. Figure 5 shows the breakdown of biomass residues and waste in California. Some of these residues and waste are used in making wood products, compost, electricity, and other products; but the vast majority is burned in the field, buried in landfills, or left untreated. This total volume of wastes is expected to continue to grow because of: 1) population increases; 2) increasing regulatory limitations and costs for disposing of biomass through burning or landfilling; and 4) a significant volume of forest residue that needs to be disposed of to reduce wildfire threats.

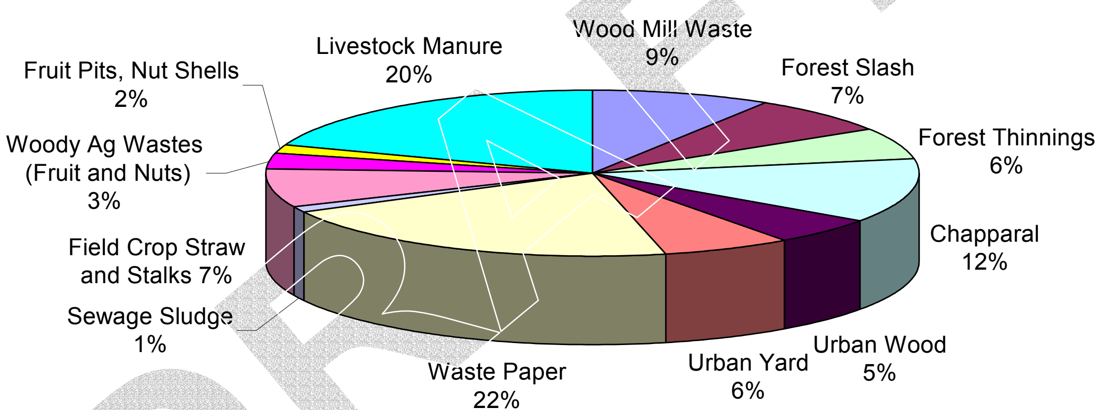

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Figure 5. Biomass Resources in California, Year 2000

(Gross Quality 61.8 million BDT)

If it is not solved, it will continue to raise a host of problems for industries and communities that need to process residues. These problems can be seen in increased production and disposal costs; negative environmental impacts; heightened public safety impacts from wildfire risk; and decreased quality of urban and rural lifestyles. The increased cost for these disposal problems will be passed on to consumers. The challenge is to create new and economically viable opportunities for farmers, foresters, fuels producers, chemical manufacturers, wood product companies, electricity producers, and consumers to use and profit from biomass commodities, products and services.

The potential for biomass for energy production is enormous and the ultimate promise, however, is that much larger fraction of California's biomass resources can be tapped at reduced cost. Utilizing biomass for energy could be used as part of a strategy to lessen carbon dioxide emissions that may contribute to global temperature patterns, reduce forest fuels to lessen wildfire risk, reduce dependence on foreign fuel, and to find technologies that will improve air quality and the environment. New, affordable, reliable, dispatchable, and improved conversion technologies are a major factor in making this happen. The choice of feedstock or biomass fuels will command which conversion technology will make the best economic option.

For direct combustion, annual biomass fuel consumption increased from about 0.5 million BDT to about 7 million BDT by 1990 (see Figure 6). As the demand for biomass supply increases, prices increases. Figure 7 shows the supply curve of biomass fuels for direct combustion in California. Currently, 4 million BDT of biomass is being used for electricity generation using direct combustion facilities

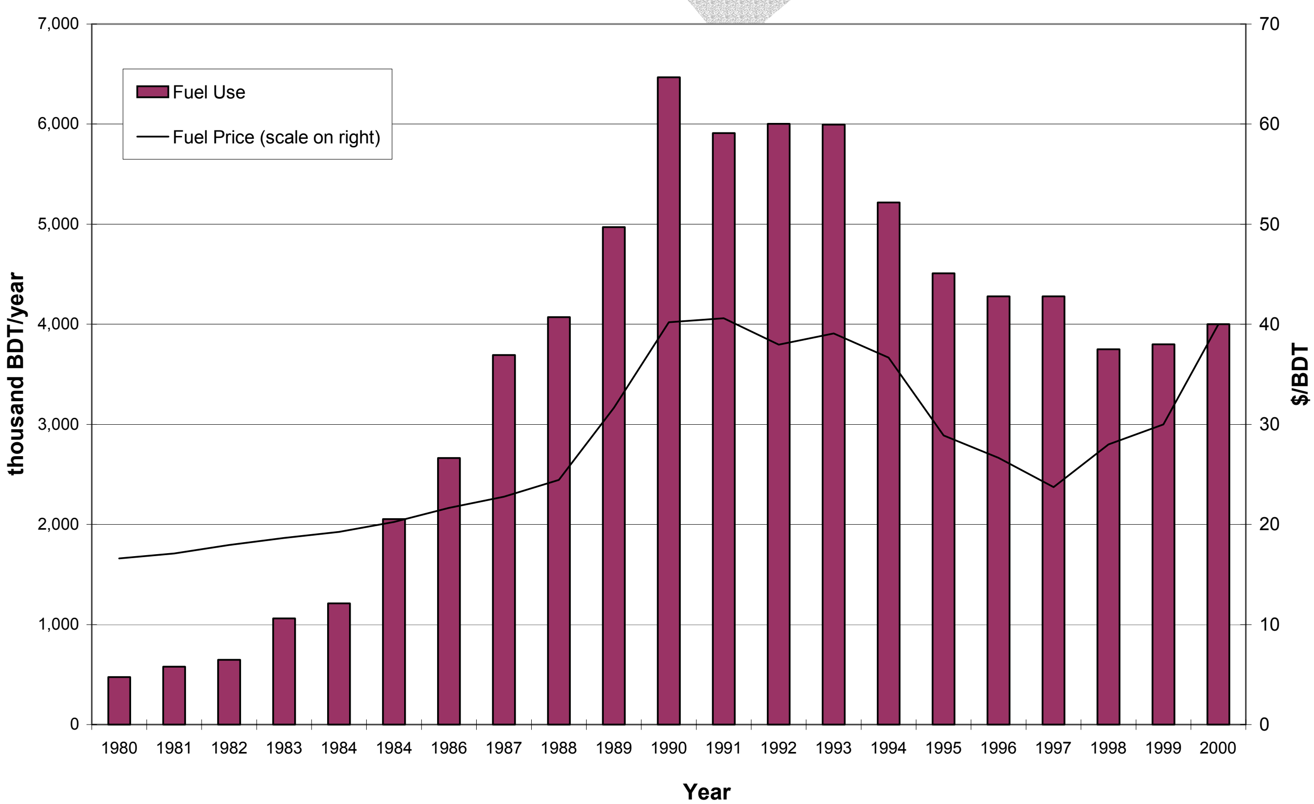
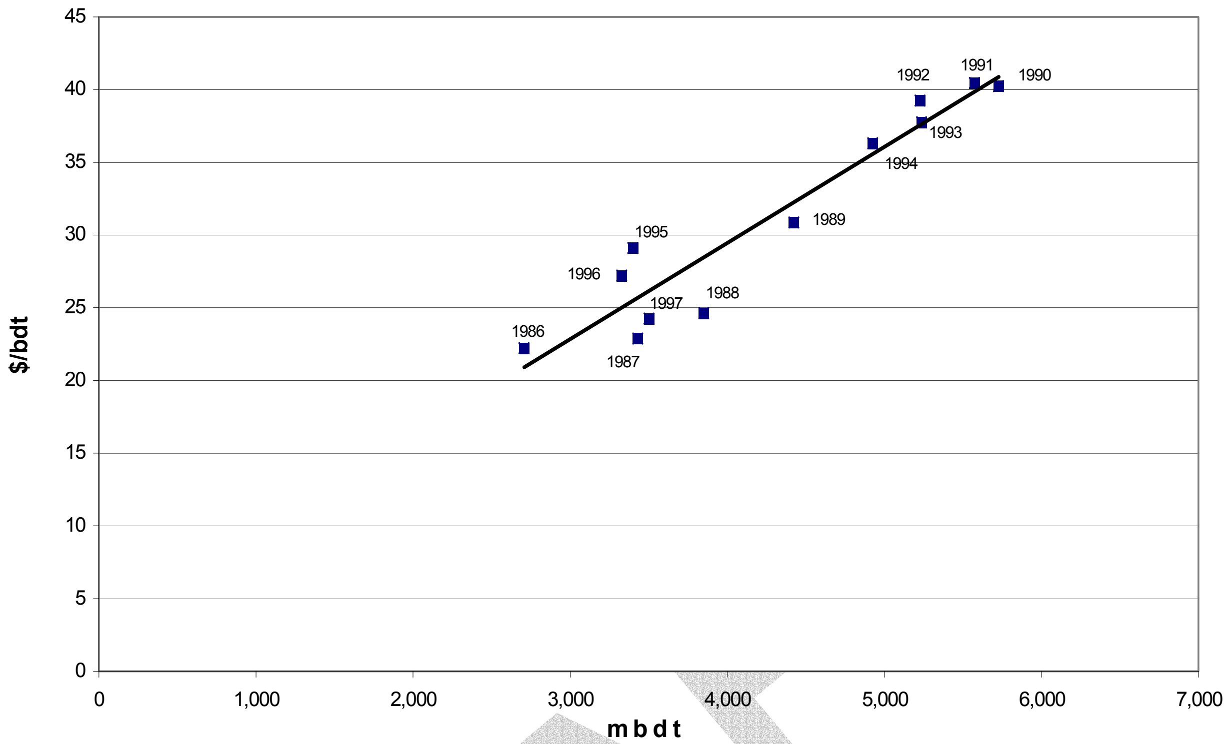


Figure 6. California Biomass Fuels Market (Direct Combustion Facilities) (5)

Figure 7. California Biomass Fuel Supply Curve, 1986-2000 (5)



B. Installed Biomass Generating Capacity

Biomass power industry in California started its commercial development in the early 1980's. PURPA and California's standard offer contracts (ISO#s) provided biomass to energy technologies a strong market development force. By 1990, California had the world's largest and the most diverse biomass power industry, with working capacity of over 1000 MW_e. Figure 8 shows the growth and decline of installed biomass electricity generating capacity in the state. This capacity peaked in 1990 from all biomass to electricity plants including direct-fired, landfill gas to energy, MSW, digester gas and biogas. The number of operating biomass power plants started to decline from 1991. Currently, the total operating capacity from these plants is about 900 MW, as shown in Figure 8. About 600 MW comes from twenty-nine direct-fired facilities, 200 MW from fifty-one LFGTE, 68 MW from three MSW plants and 26 MW from eight digester gas and biogas. Figures 9 to 12 show the maps for these plants in California.

The total electricity generating capacity in California is about 58,000 megawatts. Renewable electricity generating capacity accounts for about 30% (19,330 MW) of the state electricity generation capacity. Biomass accounts for about 5% of the renewable energy capacity.[1]

[1] Information is available at http://www.energy.ca.gov/research/PIER/documents/DRAFT_RENEWABLE2.PDF

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Of the 68 biomass direct fired power plants originally constructed: 47 were fluidized bed, 18 were horizontal grates and 14 had moveable grates. LFGTE technologies used reciprocating engines, steam turbines and gas turbines. For anaerobic digestion, the commonly used technologies are complete-mix, plug flow and covered anaerobic lagoon and using engine generator sets.

In general, the levelized cost of electricity (COE) from biomass ranges from 6-12 ¢/kWh depending on the energy conversion pathway used.

While biomass power plants received assistance from the Renewable Resources Trust Fund established in the restructuring legislation (i.e., AB 1890), they continue to have economic problems that make their future uncertain. The recent need for electrical capacity in California could help avoid the undesirable waste disposal alternatives such as land filling, agricultural burning, and fuel loading in the forest to energy production. Additional and different types of support are needed to help bring about the development of a California biomass energy industry that can play a strategic and sustainable role in California’s electricity system.

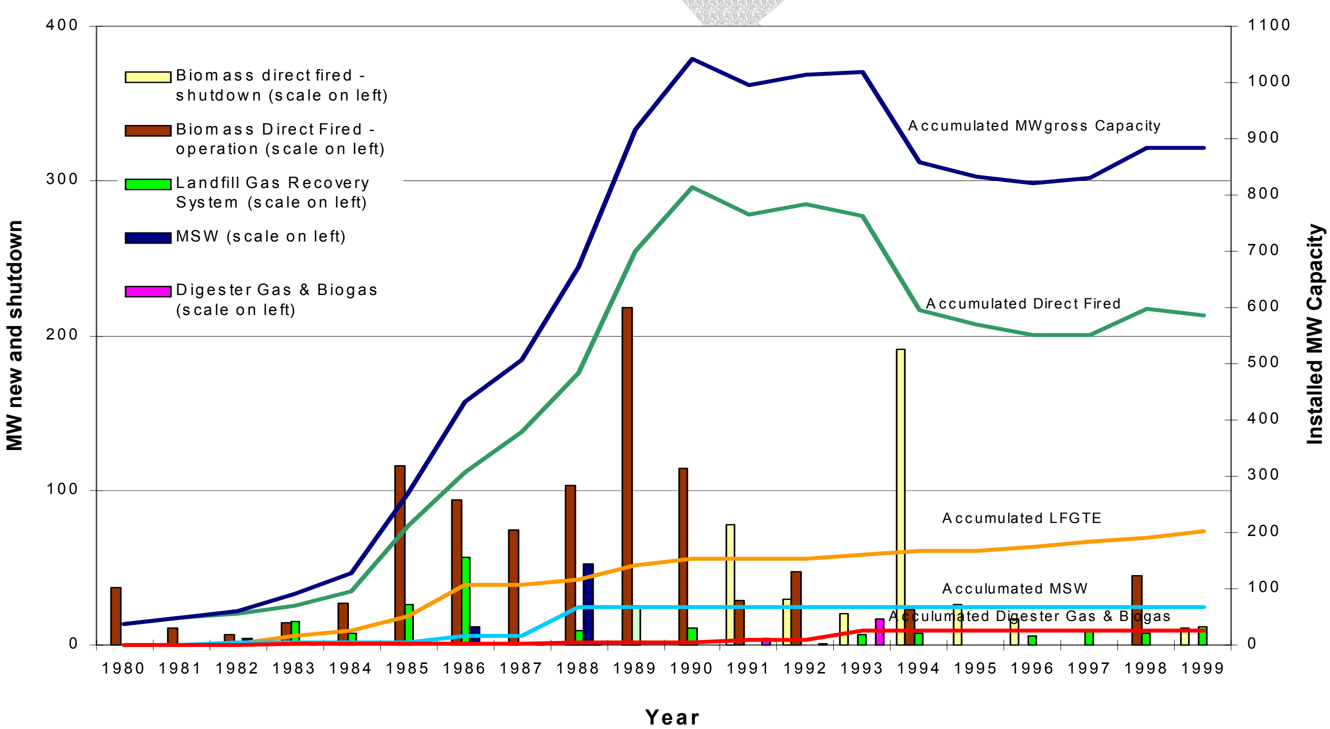

Figure 8. California Biomass Installed Capacity (MWgross)

Figure 9. Operational Direct-Fires Biomass Power Plants in California

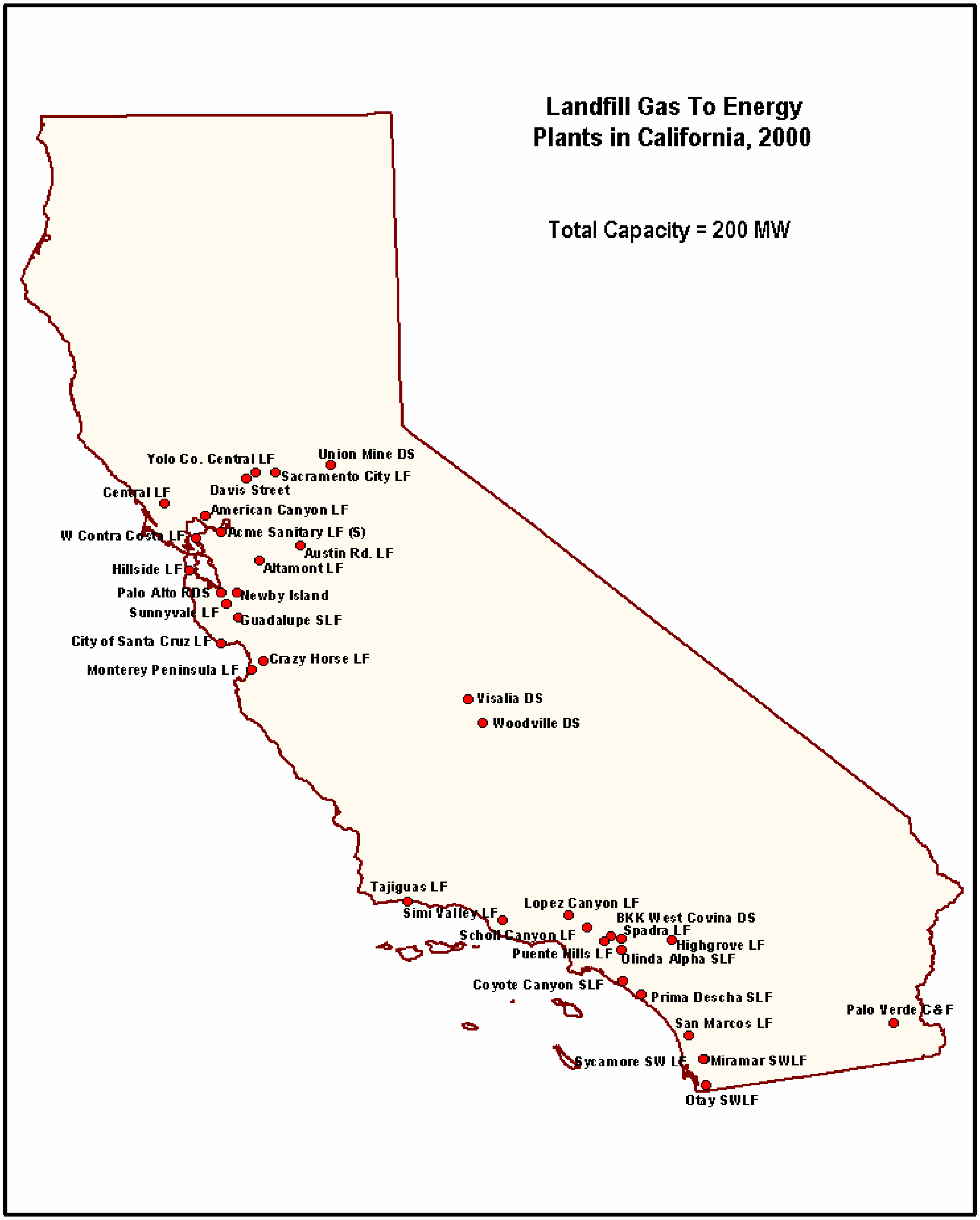

Figure 10. Landfill Gas to Energy Plants in California

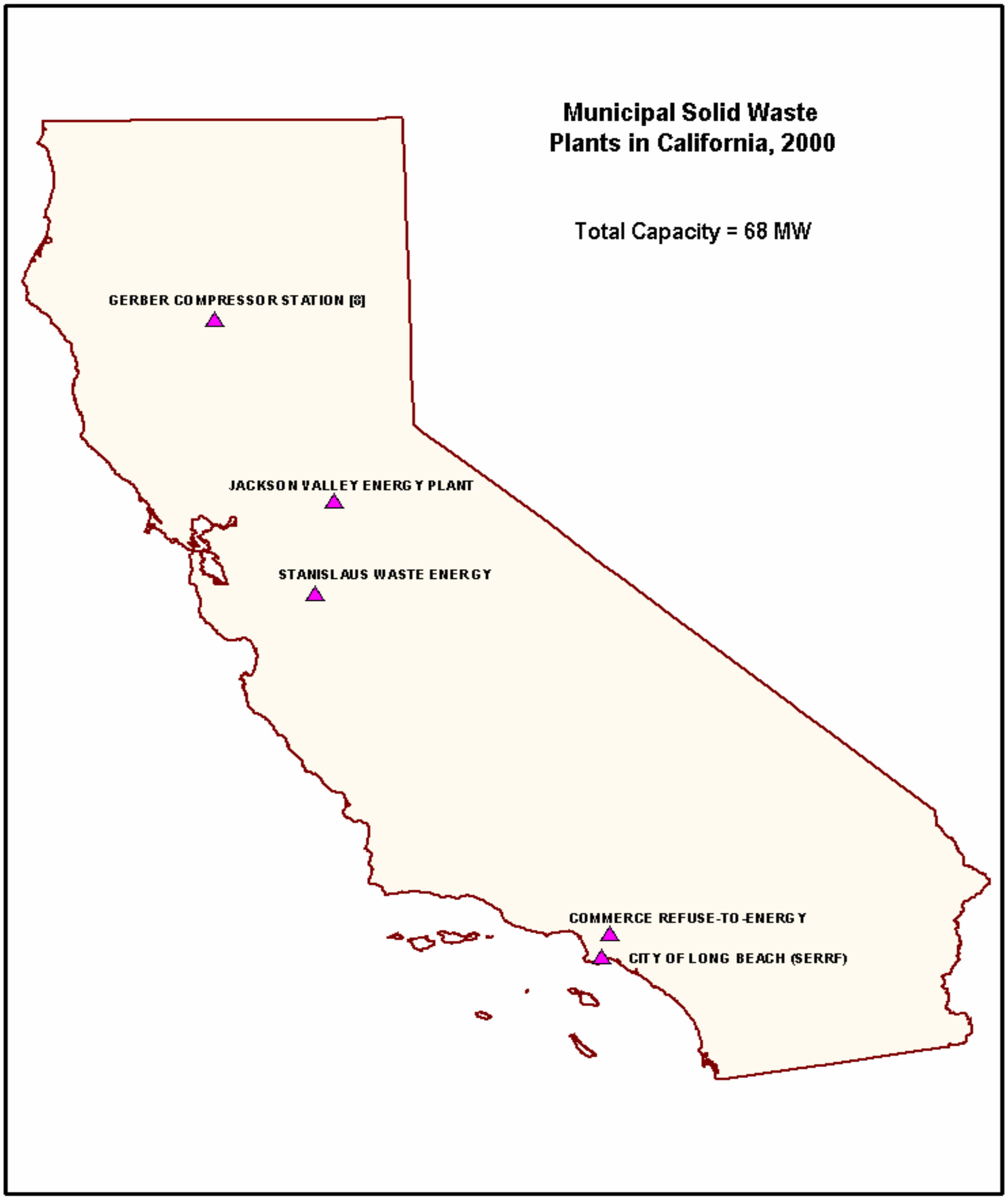

Figure 11. MSW Power Plants in California

Figure 12. Digester Gas and Biogas Plants in California

C. Delivered Electricity from Biomass Power Plants

California renewable energy production in 1999 was about 34,000 Gigawatthours. Approximately 16 percent of this delivered electricity are being contributed by biomass, as shown in Figure 13 below.

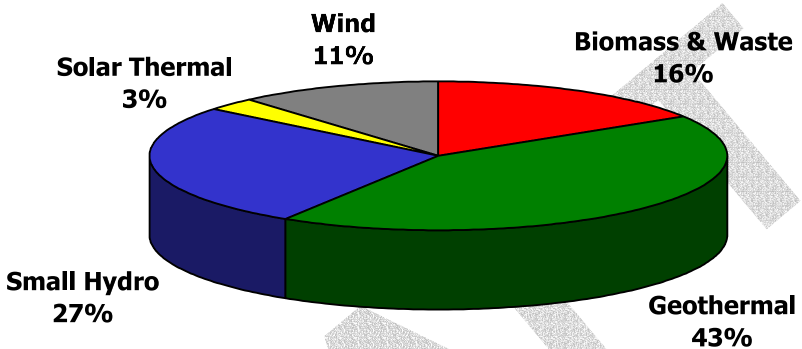

Figure 13. Renewable Energy Production in California, 1999 (34,000 GWh)

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D. Biomass Energy Technologies (and Developers) in California

Tables 2 and 5 show the developers of biomass energy conversion technologies including direct combustion, thermal gasification, biomass to ethanol, anaerobic digestion and landfill gas to energy system.

Table 2. Leading Developers of Biomass Combustion Technologies

Technologies	Government Organizations	Non Profit Organization	Industrial Firms	Leading Vendors
Stoker Boiler	DOE DOE-Regional Biomass Programs California Energy	NREL Sandia National Lab U. Hawaii U. Utah	Burlington Electric WWP Minn Power NSP	Detroit stoker Foster Wheeler Dev Corp DB Bailey T.R. Miles

	Commission	Southern Research	NYSEG Paper and forest product mills Thermo Ecotek Corp	(design and O&M) Zurn
Fluidized Bed Combustion Boiler	DOE NETL DOE Fossil Energy	NREL Sandia	NSP Tri State IVO (Finland) Thermo Ecotek Corp	Foster Wheeler DB Bailey McDermott B&W EPI (Idaho)

Table 3. Leading developers of Thermal Gasification Technologies

Technologies	Government Organizations	Non Profit Organization	Industrial Firms	Leading Vendors
Small Scale Gasification	DOE Biopower California Energy Commission	NREL	Community Power Corp	CPC Carbona
Gasification Combined Cycle	DOE Biopower Various national governments European Union	World Bank (Global Environment Fund)	IGT Sydkraft (Sweden) Shell (UK) TPS (Sweden)	FERCO (Battelle gasifier) Foster Wheeler Dev Corp (US Finland) Carbona Kaeverner

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Table 4. Leading Developers of LFGTE and Anaerobic Digestion Technologies

Technologies	Government Organization	Non Profit Organization	Industrial Firms	Leading Vendors
LFGTE	DOE USEPA	EPRI	GRI	
Anaerobic Digestion of Livestock manure and other fuels	DOE Regional Programs			Microgy

Table 5. Leading Developers of Biomass to Ethanol Fermentation Technologies

Technologies	Government Organization	Non Profit Organization	Industrial Firms	Leading Vendors
Dilute Acid hydrolysis	DOE California Energy Commission	NREL	BCI Iogen HAFTA	Ogden Collins Pine Co. RKAII Nofsinger
Enzymatic Hydrolysis	DOE California Energy Commission	NREL	BCI Iogen	Ogden Collins Pine Co. RKAII Nofsinger
Concentrated Acid	DOE	NREL	Arkenol Masada Resource Corp	Arkenol
Gasification-Fermentation	DOE	NREL	Jim Gaddy's	

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III. Benefits Provided by Biomass Energy in California

Biomass to energy (or bioenergy) holds great promise for playing a significant role in California's energy future and for dramatically enhancing the state's economy and environment. The development of strong California bioenergy industry can contribute to:

A. Enhanced Economic Growth

California's bioenergy industry, with synergy between biomass generators (growers, farmers, foresters and livestock operators), biomass processors (and recyclers), biomass users (product manufacturers and biomass power plant operators), creates new markets and increases the use of biomass resources in such a way to provide economic and employment benefits to Californians. These foreseen benefits maybe captured most likely in economically stressed regions and supplying competitively priced electricity in capacity constrained locations.

California's biomass to electricity provides economic and employment benefits. For example, the current California biomass direct combustion to electricity industry involves an investment of over $1.6 billion (in 1992$), supports $700 million/year of Gross State Product, employs over 5,000 people, and generates about $30 million/year in tax revenue to the State. For over 800 MW of biomass-fired capacity that was on-line in the state in the early 1990s, the value of the overall benefits was estimated to be about half a billion dollars annually (Natural Resource Strategic Services (6). About 75% of these benefits resulted from wages paid to facility workers and from tax base impacts like property taxes. Potential beneficiaries of these benefits are also shown below.
The estimated value of economic benefits are indicated below:

Table 6. Benefits of Direct-Fired Biomass to Electricity Industry

Benefits	**$**	**Beneficiaries**
Open burn emission reduction value:	$15,395,196	California residents Local air districts
Wildfire emission reduction value:	$ 2,020,275	California residents Local air districts
Landfill capacity extension value:	$20,624,300	Landfill owners Integrated Waste Management Board California residents
Wildfire risk reduction value:	$23,291,405	Local property owners USFS/CDF California residents
Forest health improvement value:	$ 560,000	Local property owners
Alternative agricultural disposal value:	$21,824,964	Ag growers & producers
Added economic value:	$67,652,774	Employees- local &

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		state government
Employment income value:	$165,450,561	Employees- local & state government
Replacement energy value:	$156,111,270	Plant owners, electricity customers
Total	**$472,930,745**	

Existing, new and emerging bioenergy technologies such as LFGTE, MSW, digester gas and biogas are also providing benefits, however, not quantified yet. All of these technologies have the potential to make not just affordable electricity, but also other fuels, chemicals, pharmaceuticals and other value-added products.

Technical advances in these technologies can create an expanding array of exciting new business and employment in the state. In rural and urban interface communities, uses other than the production of fuels or electricity also will be developed. Utilization of biomass in products including mulch, horse bedding, specialty wood products, planting medium, sod for grass, vermiculture, and lumber from logs harvested in urban forest management will also create jobs and increase flow of revenues.

Strategic RD&D and deployment of distributed generation such as small modular technologies and other niche bioenergy technologies can help improve affordability, reliability, safety and power quality to the state's electricity system. Ethanol fuels resulting from accelerated developments of co-located biomass to ethanol facilities could be used as substitute to MTBE. Successful collection and use of approximately 5 million tons per year of biomass residues could generate as much as 300 to 500 million gallons of ethanol annually, along with a variety of other saleable products.

B. Improved Environmental Quality

Thermochemical conversion of fossil fuels produces deleterious emissions – including nitrogen oxides and sulfur dioxides – degrading air and water quality. Carbon dioxide is also being emitted, a primary greenhouse gas contributing to global climate change. Thermochemical and biochemical conversion pathways of biomass are more environmentally friendly option. The environmental benefits of using biomass resources for electricity production and co-production of ethanol and other associated value-added products is perhaps the most significant driving force encouraging the retention and/or expanded use of biomass as a competitive option in the context of electricity deregulation.

Retaining the existing biomass to electricity technologies can help reduce open burning of over 1.2 million tons of agricultural wastes, reduce 1,400,000 to 1,500,000 tons per year of forest wastes subject to both open burning and wildfire. In addition, these technologies reduce PM10 emission of about 1,600 tons from agricultural open burning and 300 tons from wildfires and forest open burning. It also offers diversion of waste

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from landfill and extension of landfill capacity and life. Materials diverted from landfills and used as fuel ranged from just over 800,000 tons per year in 1991 to over 1,600,000 tons per year in 1994.

Further deployment of bioenergy technologies can help prevent wildfires, reduce air pollution emissions from open-field burning, and decrease landfilling of non-recyclable woodwastes. Open field burning of rice straw is being phased-out and rice straw biomass to energy facilities could further reduce air pollutants and divert municipal solid wastes from ending up in landfills. For example, co-locating biomass conversion technologies at just 10 existing biomass conversion facilities could divert more than 2 million tons per year of biomass residues from landfills.

Converting forest slash and thinnings to energy can help improve forest health and reduce the risk of catastrophic wildfires that cost the state from $600 millions to over a billion dollars a year.

C. Improved Public Health and Safety

Thermochemical and biochemical conversions of biomass to energy avoid forest wildfires, which provide a greater degree of security, safety, and stability to interface communities, those populations living closest to forests, throughout the state. There is a significant risk of damage due to uncontrollable wildfires to these interface communities, and the deployment of biomass conversion facilities in these areas may lessen the risk of such wildfires. These facilities could serve as a convenient disposal point for forest thinnings, which if left undisturbed, could cause catastrophic wildfires. Forest health improves, productivity increases, and avoided loss of recreational values, structures and timberlands due to vegetation removal and improved forest management. Estimates of reduced risk of wildfires range from 50,000-60,000 acres per year to a potential of treating 100,000+ acres per year or more.

As urban communities expand into more rural areas, and as the agricultural activity of the state increases, the need for alternatives to open field burning of agricultural residues such as rice straw arises. Biomass conversion facilities may serve as a convenient disposal alternative to the cultural practice of open field burning. This in turn may result in a significant improvement in the air quality in urban areas that surround regions of high agricultural activity.

Biomass conversion facilities may assist the state in achieving its stringent recycling goals. This in turn could potentially help the state to conserve landfill space and extend the useful life of these landfills.

The state-mandated phase-out of MTBE on December 31, 2002 may serve as a catalyst for the use of ethanol as an environmentally friendly oxygenates. MTBE has been shown to be a recalcitrant contaminant of the state's drinking water, and considerable evidence indicates that MTBE is a carcinogen and potential health hazard.

More importantly, converting biomass to energy and other value-added products lowers the risk of human health problems and forest diseases.

D. Information Benefits

The distribution of information regarding biomass to energy technologies is likely to increase the awareness of such technologies among key policymakers and the general public. There is general agreement that steps must be taken to dispose of the various biomass residues and wastes in an efficient and environmentally friendly manner, but questions still remain as to the most appropriate technology options. By actively compiling information on the various process options and the advantages and disadvantages of biomass to energy, informed decisions can be made as to the most appropriate and sustainable technological route.

Biomass energy production in California provides significant public information benefits such as: cleaner air through reduced emissions; reduced fire hazards through fuel removal; improved forest productivity through timber stand enhancement; extended landfill life through fuel diversion and utilization; alternative disposal mechanisms for agriculture; employment in rural areas; tax revenues in rural areas; and clean, renewable and dispersed energy sources.

E. Enhanced state's security and minimized risk

As an indigenous and locally available energy resource, biomass to energy can substantially improve our state's energy independence and security, and help the state minimize disruptions in the supply of electricity to the power grid. Today, the state needs extra capacity to meet the electrical demand, wherein supply is decreasing. Electrons are being imported from other states to meet California needs. Increase use of biomass for electricity production can provide a domestic alternative to imported electrons. It may aid in securing increased capacity and dispatchability of electricity, especially in congested, high demand, or strained areas. Any surpluses of electricity produced via new, emerging, or distributed small modular and co-located electricity and ethanol production could potentially be shunted to the power grid quickly and efficiently, and during times of peaking, these facilities may serve a crucial role as power providers.

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IV. Issues Facing Biomass Energy in California.

The issues described below are generic for all thermochemical and biochemical energy conversion systems described in Section I. In particular, these issues are tied to electricity production.

A. California's Electricity System: Reliability, Power Quality and Dispatchability Issues

Electricity use in California is increasing with potential adverse impact on energy availability and cost. Basic growth demographics in California shows that there will be an increasing demand for electricity, often "on peak". Electricity demand is increasing faster than new supply. Notably, end users require higher power quality and more reliable power. Hence, reliability, power quality and price volatility are crucial issues confronting California's electricity system. Utility requests for a number of large-scale customer curtailments and the recent blackouts affecting over 100,000 electricity customers in the San Francisco Bay Area illustrate the problems in system reliability. Similarly, the doubling of electricity prices paid by residential and commercial customers in the San Diego region and the recent shortage of capacity in California demonstrate the susceptibility of the system to price volatility. Overall, wholesale electricity prices during June of 2000 were 270 percent over prices during June of 1999, resulting in over $1 billion in increased payments for electricity.

The decrease in system reliability is closely tied to increasing electricity demands, an aging generation and transmission system, and a steadily declining reserve margin. Electricity supply and demand are out of balance now in the state. Electricity use is increasing, and new supply is not keeping up with the demand. The rising peak demands especially in summer and winter times threatens reliability. There is a need to balance electricity and its impact to the environment as well. The present market structure, fuel shortages, emission allowances and high peak demand produce market uncertainties and price volatility. In addition, more end users nowadays require higher quality and more reliable power.

In particular, California's population is growing by a half a million people per year. In the next decade, California's population is expected to grow to 40 million people and the associated electricity demand will increase by twenty percent over 1999 levels. In contrast, there has not been an equivalent development in California's electricity transmission and generation capacities. Historically, electric utilities provided investments for new power plants and transmission lines in exchange for a guaranteed financial return. Under electricity restructuring, there have been no significant additions to California's transmission infrastructure. Similarly, development of in-state generating capacity in California has been slow. Without new in-state generating capacity, California electricity customers will become increasingly reliant on imported electricity and that much more subject to electricity system disruptions. Consequently, each

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megawatt of in-state capacity that can be brought on-line during times of peak demand is important. Located throughout the state, California's biomass-fueled power plants could help provide needed peak electricity as well as base load electricity for future demand growth. Yet, there has been a steady decline in biomass power plants since the mid-1990 due to changes in electricity purchase prices and the structure of the electricity system as mentioned previously. Additional and different types of support are needed to help bring about the development of a California biomass energy industry that can play a strategic and sustainable role in California's electricity system.

B. Economic Issues

1. Cost Competitiveness:

Biomass energy facilities are relatively capital intensive (comparable to coal and natural gas) and they are generally being operated as baseload stations to make the investment economic. The cost-of-electricity (COE) is a common figure of merit used to compare generation alternatives. This is normally reported as levelized cost of electricity. A high capacity factor reduces the impact of the capital cost component of the plant COE. This increases the relative importance of biomass fuel and other operating costs as components of COE. Once a project is operational, the plant will be dispatched solely on its relative cost to operate compared to other plants in the system. Thus, for example a biomass power project to contribute value to the electric utility system, operating costs must be competitive with other choices. The primary drivers for operating costs are station heat rate and fuel cost with low heat rate and fuel cost being the winning combination.

In a deregulated market electricity generators can sell power in several different ways: as bulk power into the Power Exchange (PX); as an adjustment to electrical imbalances, congestion or reliability through the Independent System Operator (ISO); or directly to customers through private contracts. Electricity sales through the PX are conducted on an auction-like basis to match total electrical demand to power generation. The PX accepts requests for specified quantities of electricity at specified prices on a day to day and hourly basis. In turn, the PX allows generators to bid electricity deliveries a day in advance on an hourly basis. An hourly-based spot market or electricity pool is created from the auction, and the PX purchases electricity from the lowest bidders until there is sufficient supply to meet the demand. Fluctuations in demand result in variations in price hourly, daily and seasonally.

Figure 14 shows average PX market clearing prices for 1998, 1999 and 2000. Forecast for year 2001 is also included. In 1998 and 1999, average PX prices have tended to stay between 1.0 to 5 ¢/kWh, reflecting the high degree of competitiveness in the bulk electricity marketplace. The low prices received for bulk electricity sales through the PX make it difficult for biomass to compete against less expensive electricity sources.

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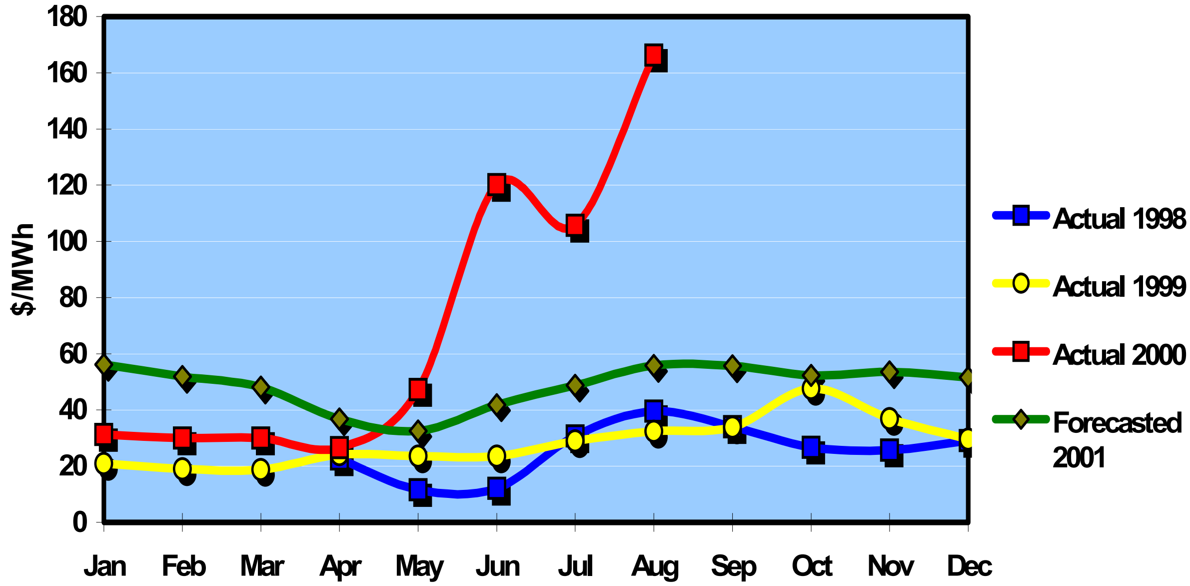

Figure 14. Monthly Average PX market clearing prices, 1998-2000[2]

It is important to reduce the cost of biomass energy systems to improve their value as part of the overall electricity system and sustainability. To be market competitive, research and development is needed to lower capital costs, improve conversion efficiency and reduce O&M costs. A study was conducted at the Commission on the economic impacts of barriers in terms of percentage cost of electricity. Figure 15 shows the relative impacts of barriers.

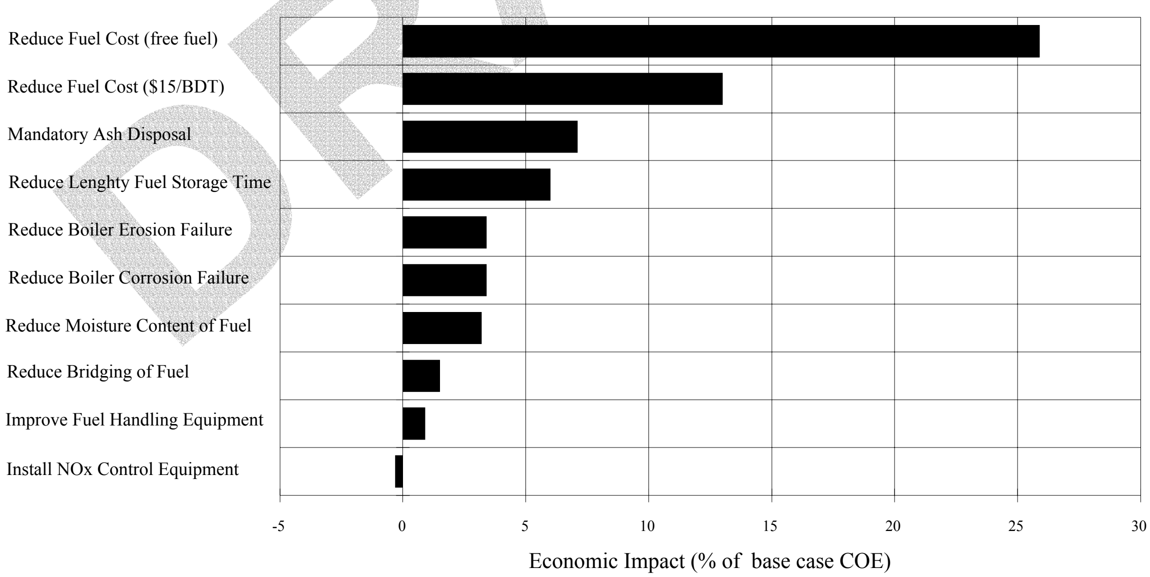

Figure 15. Summary of the Economic Impacts of Various Technical and Environmental Barrier Mitigation Approaches

[2] Bob Grow's Presentation, California Energy Commission, Sep 2000.

Of all the economically quantifiable barriers to direct-fired plants, fuel cost has the greatest economic impact. For a base case fuel cost of $30/BDT, BIOPOWER model found the cost of electricity to be 8.8 cents/kWh in constant 1994 dollars. For fuel costs of $0/BDT and $15/BDT, BIOPOWER found that the cost of electricity was 6.6 cents/kWh and 7.7 cents/kWh, respectively. These values amounted to about a 26% and 13% reduction in the overall base case cost of electricity, respectively. The most successful way of minimizing the cost of urban wood waste and forest residues (the most predominant fuels used in the biomass industry) is to reduce the chipping costs and transportation costs. The chipping cost can contribute almost 40 percent of the total production cost of the fuel.

The second way to decrease the fuel cost is to minimize the transportation distance or to consider the back-hauling practice. The transportation cost can be as high as $10/BDT for a round trip of 25 miles. If back hauling is used, the transportation cost can be reduced by as much as half. However, back hauling may not always be utilized since biomass transportation routes may not always coincide with well-established trucking routes.

In addition, R&D efforts should take into account opportunities for biomass to be competitive in niche markets as a way of eventually working their way into a position of broad market competitiveness. Biomass energy systems should be designed or marketed to receive economic rewards for non-energy benefits they provide. Furthermore, co-production of value-added products is now needed to improve the economics of the project in today's deregulated electricity market.

2. Low Cost Power Generation Options

Natural gas prices have remained relatively low in recent years, while natural gas combined cycle plants have increased the efficiency of power production dramatically. This price moderation for what is usually viewed as a premium fuel has allowed electricity generation costs to approach 2-4¢/kWh with this fuel source. To be competitive with gas-fueled technologies, biomass electricity generation costs should approach 2 - 4 ¢/kWh at today's natural gas prices. Figure 6 illustrates the price ranges for various energy resource options.

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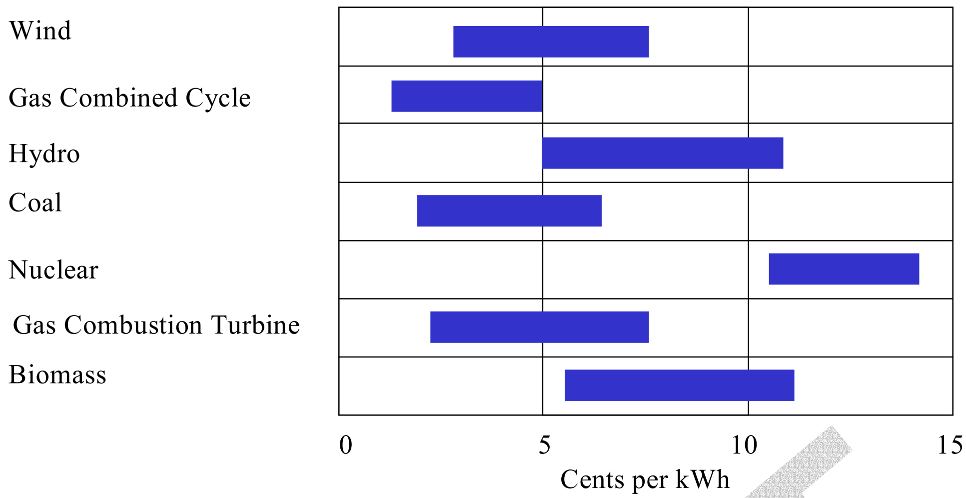

Figure 16. Comparison of Levelized COE from Various Energy Generating Sources (7)

Although more regional in nature hydropower costs are in this range as well or even lower especially in winter times. Re-licensing issues surrounding existing hydro sites are expected to significantly constrain the use of this resource. Because the natural gas option is widely available, it has become the standard for many utilities in setting a floor on resource options, i.e., California Power Exchange. More recently, however, gas prices have begun to rebound and will probably escalate at a moderate level during the rest of the decade and may make biomass and other renewable energy a preferred option.

For biomass to ethanol to compete with the maturer petroleum- and corn-based ethanol industries, in particular, Midwest corn to ethanol and Mideast crude oil must rely on the refinery concept in order to remain economically viable. In addition to ethanol or gasoline, these two industries must produce other specialty, low-volume, high value added products in order to remain economically viable. In particular, the petroleum industry must produce commodity chemicals with very high economies of scale in order to turn a profit. Moreover, even with a federal subsidy of 54 cents a gallon, the corn-based ethanol producers must produce other products such as distillers dried grain with soluble (DDGS)- a type of high protein animal feed, and corn oil in order to remain profitable. In other words, a corn to ethanol producer that only produced ethanol, or petroleum company that only produced gasoline simply would not survive. In these more mature industries, the cost of the feedstock is said to be 65 to 70% of the total production costs. The chemical components must be optimally used, and the levels of production of product streams must be adapted to meet current market demands. A California biomass to ethanol industry must also make the best economic uses of the chemicals in its feedstocks. The industry has to have the ability to adapt its output of various products to market demand.

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3. Feedstock Collection, Availability and Cost

Feedstock availability and cost strongly influence the COE associated with biomass power facilities. Biomass feedstock collection can be labor intensive, especially when obtained from the rice field for rice straws and the forest floor for forest slash and thinnings. Through the use of the Energy Commission's BioFuel Model, the costs (in 1994 current dollar) for various processed biomass fuels were projected for California: energy crops are about $45/BDT, timber stand improvement residues (forest thinnings) are about $31/BDT, urban wood waste residues are about $22/BDT, rice straw residues are about $44/BDT, and orchard prunings are about $26/BDT (Table 7).

Table 7. Estimated Costs of Different Biomass Residues by the BioFuel Model (in 1994 current dollar)

	Energy Crops	Forest Slash/ Thinnings	Urban Wood Wastes	Rice Straw	Orchard Prunings
Land	7.1	N/A	0.0	N/A	N/A
Establishment	7.2	N/A	N/A	N/A	N/A
Cultural Management	34.3	N/A	N/A	N/A	N/A
Annual Operating	N/A	N/A	4.4	N/A	N/A
Harvest/Collect /Process	21.1	23.9	9.7	24.4	19.6
Transportation	5.1	7.0	7.7	19.9	6.5
Total ($/BDT)	**44.8**	**30.9**	**21.8**	**44.3**	**26.1**

*N/A: Not Applicable

These figures depend heavily on the machine operating conditions, management systems, financial arrangements, and resources of a particular biomass processor. To determine the effects of various technical and environmental barriers on the base case fuel cost, different scenarios were developed by varying the operating parameters of the base case. For energy crops, the irrigation cost had the greatest economic impact on the cost of fuel. The irrigation cost is capable of increasing the base case cost of fuel by as much as 74%. For rice straw, drying the straw in the field before collection can reduce the processing cost by as much as 73%; and for orchard prunings, reducing the number of field workers in the chipping process can reduce the cost of fuel by as much as 29%.

Also, because biomass has a higher bulk density per unit heat input than coal, it has higher associated transportation, processing and handling costs. Environmental concerns (i.e. spotted owl habitat, wildfires) have greatly affected the timber industry. This directly affects the feedstock availability for biomass power plants in that region. In California, the rapid development of biomass power facilities in the 1980s created a high demand,

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causing biomass fuel prices to skyrocket. Furthermore, as pulp and paper mill operations become more efficient, there is less byproduct resource available. Competing end-uses for biomass resources, such as composting, materials for construction, animal bedding and landscaping mulch, maintain demand-side pressure.

Countering those forces to some degree are trends such as the mandated restrictions on landfilling, phasing out of open field burning or rice straws, phase-out of MTBE and avoidance of forest wildfires, that may increase the availability of process byproduct resources in the market. As soon as biomass to ethanol becomes commercially available using more biomass fuels, co-located facilities will want to become more self-sufficient in power, and co-produced other value-added products with high economic value.

4. Financing/Lending Institutions

Another obstacle encountered in the today's markets for new and emerging biomass energy facilities is securing financing. Securing financing for biomass projects, such as co-located biomass to ethanol and anaerobic digestion facilities, can be more difficult than for conventional projects due to higher perceived risks. For all independent power projects, the recent trend of requiring a higher equity stake on the part of the developer is forcing technology toward the tried and true. Lending institutions are very reluctant to finance the construction of biomass to energy projects without an established long-term fuel supply infrastructure and guarantees. A power plant will not be financed without a fuel supply infrastructure, and the fuel supply infrastructure will not be created without a market for the biomass fuel. In addition, despite the need for the use of higher efficiency conversion systems to make biomass power fuels competitive, most lenders are uncomfortable with new or unfamiliar power generation technology. Thus, perceived risks in financing can be a significant hurdle to the introduction of the technology that is needed to move the industry forward.

C. Environmental Issues

1. Diminishing Waste Disposal Option

Approximately 60 million bone dry tons of biomass residues are generated each year in California. This total volume of wastes will likely continue to grow because of: 1) population increases; 2) increasing regulatory limitations and costs for disposing of biomass through burning or landfilling; and 4) a significant volume of forest residue that needs to be disposed of to reduce wildfire threats.

While the volume of biomass residues requiring treatment is increasing, California's ability to use biomass residues for useful purposes is decreasing. In particular, use of residues for electricity generation has declined significantly in the past five years. When California's biomass to electricity industry reached its peak level of production in the early 1990's, it acted as repository for over seven millions tons of biomass residues. For variety of reasons, California's biomass-fueled generating capacity has declined about a third. Fundamentally, the decline in California's biomass-fueled electricity capacity is due to the high cost of biomass electricity production relative to other generation sources, and to significant electricity market structure. Further, existing capacity to dispose of biomass by generation could also decline. Further declines in California's biomass-fueled generating capacity seem likely. Currently available renewable production credits, now part of the electric utility restructuring plan, end in 2001. Biomass industry representative have indicated that more plant closures or cutbacks in operation will occur without continuation of production credits, or other forms of support that recognizes the wide environmental benefits of biomass.

Still more broadly, failure to address the waste disposal issue raises a host of problems for industries and communities that need to process residues. These problems can be seen in: increased production and disposal costs; negative environmental impacts; heightened public safety impacts from wildfire risk; and decreased quality of urban and rural lifestyles. The three major unique issues deal with agricultural residues, forest slash and thinnings and mixed solid wastes.

a. Agricultural Residues

Historically, agricultural residues in California such as rice straw and orchard prunings has disposed of by open field burning. Lignocellulosic agricultural residues that can be produced in the state are over 13 million BDT/yr. Because of the air pollutants released to the atmosphere through open field burning, federal, state and local air quality agencies have been tightening the regulations on open field burning. Rice straw is the first agricultural waste that reduction in open field burning is mandated (Rice Straw Burning Reduction Act of 1991). This Act mandates a 75%-100% reduction of open-field burning of rice straw, by the year 2000. The current rice straw production in California ranges from 1.0 to 1.5 million BDT/year. Even though agriculture is California's number one industry, its population is 94+% urban and its increasing. There are conflicting regulations on open field burning versus landfilling.

b. Forest Slash and Thinnings

Another related concern is the growing volume of dead/diseased trees, forest slash and thinnings that increases fuel loading and worsens forest health. If harvested and collected, forest slash and thinnings can be up to 18 million BDT/yr. Wildfire hazards (see Figure 17 below) are critical on many forested lands, foothill, mountain home sites and other business properties in California.

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Courtesy of John McColgan: Wildfires

Figure 17. Forest Wildfires

Thinning out trees for timber stand improvement and removing shrubs and other flammable vegetation will help assure the survivability of the remaining trees. Excessive amounts of fuel have built up in forests and woodlands of the state since fire can no longer be allowed to perform its ecological role. When devastating fires break out, many of the native trees, homes, businesses and other properties can be destroyed in a few moments. Approximately over a billion dollars in costs/losses are incurred in the state from wildfires annually. The fuel loads on these forested lands and wooded and brush-covered parcels must be properly managed to survive the next wildfire. These forest health problems and the damage caused by catastrophic wildfires have reached a level of urgency that calls for new solutions. There are conflicting regulations on wildfire prevention versus timber sales.

c. Mixed Solid Waste

Mixed solid waste (including yard waste, construction waste, urban wood waste, paper products) is increasingly a problem in the state. According to California Integrated Waste Management Board, Californians create nearly 2,900 pounds of household garbage and other industrial waste each and every second; a total of 45 million tons a year. Until recently, the only place to dispose of that trash was to local landfills. Constraints on landfill capacity led to the passage of legislation in 1989, the California Integrated Waste Management Act. This Act mandates stringent goals for diverting solid waste from landfills into reuse, recycling or transformation to energy products. Municipalities operating solid waste disposal facilities were required to divert 25% of the waste stream to these uses beginning in 1995 and must attain 50% diversion rate by the year 2000. A subsequent law (Assembly Bill 688) set forth additional conditions for calculating the credits for diverting waste materials and limited the degree to which biomass transformation (either combustion or fuel production) could be counted as satisfying the diversion requirements. There are conflicting regulations on recycling mandates versus limit on transformation facilities.

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2. Water Quality and Use

For the traditional ethanol production processes, mainly starch-based feedstock, it has been estimated that for every liter of ethanol produced results in at least 14-15 liters of wastewater. Although it is possible to recycle wastewater and water used in the various processes, each step in the biomass to ethanol process will require the addition of large amounts of water in order to be effective. It is likely for lignocellusic biomass feedstock; wastewater produced will be higher than the traditional method.

However, several limitations prevent large-scale recycling of wastewater. The first is the fact that in traditional ethanol processes, the effluent from the process tends to have very low pH and very high biological oxygen demand (BOD). Before it can be safely discharged, the pH must be raised to a neutral level and the BOD must be reduced to acceptable levels. Because of its high BOD and low pH, or potential nutrient content, many have considered it ideal to recycle the wastewater back into the fermentation process, where low pH and relatively high nutrient levels are required.

However, the wastewater stream typically contains compounds inhibitory to growth, such as fusel oils, acid mediated glucose degradation products, and protein based hormones, which in large quantities can inhibit fermentation. These compounds often are difficult and costly to separate from the wastewater. Finally, many of the processes under consideration require the use of highly corrosive and environmentally poisonous compounds, such as ammonia, halogenated acids, and organic solvents, mixed with water during pretreatment and hydrolysis. Although it may be possible to fully recover these compounds, complete recovery is not only costly, but also likely to be incomplete, and would necessitate wastewater treatment before discharge.

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Moreover, certain process schemes, such as simultaneous saccharification and fermentation (SSCF), call for the use of both glucose and xylose at the same time. All organisms capable of producing ethanol display diauxic, or preferential growth, meaning that, when given both glucose and xylose, the organism will exclusively ferment glucose efficiently to completion, and then switch to the less efficient fermentation of xylose. Xylose fermentation leads to formation of a dead-end and inhibitory five carbon compound called xylitol. The recycle of wastewater may be further constrained by the presence of xylitol, a non-fermentable and inhibitory compound, in large quantities.

3. Carbon Dioxide/Greenhouse Gases

One of the more attractive environmental benefits of biomass to energy conversion systems is the possibility of zero net contribution to the amount of CO_2 in the atmosphere. Carbon dioxide has been identified as a greenhouse gas, and carbon dioxide emissions from the burning of fossil fuels have been implicated in the recent trend of global warming. Continued development of biomass energy conversion systems and its use could significantly reduce greenhouse gases. Generally, when based solely on CO_2

emissions reductions from electricity generation, biomass resources are preferable to traditional fossil fuels.

4. Environmental and Permitting Regulations

A recurring concern echoed throughout the industry is dealing with variable and changing permitting requirements. Federal, state, and local regulations present a veritable maze to the biomass to energy conversion developer. In addition, biomass to energy is seen as a relatively new technology concept where many regulators are concerned. Therefore, whenever a developer (such as biomass to ethanol and anaerobic digestion) is applying for permits, he must first educate the appropriate regulators concerning biomass technology. This has the practical effect of sending the permitting process back to square one for every new biomass to energy plant, where each aspect of the plant must be documented and/or proven, over and over again. This approach may also be seen as unnecessarily burdensome, given the potentially beneficial environmental aspects of biomass to energy conversion options compared to some conventional plants. It is hoped that once regulators are educated as to the benefits of biomass to energy facilities, some of this repetition could certainly be eliminated (placing biomass on at least an equal footing with conventional power sources), and perhaps even some informal streamlining could take place. An example presented to the survey team indicated that the permitting process for a new plant took three years and cost $3 million. Streamlining the permitting process would be a logical step for organizations hoping to encourage the use of biomass energy.

5. Externality Considerations

Valuing externalities or the true value of benefits such as environmental and economic benefits or impacts may help in the choice of power generation options. These externalities tend to level the playing field for biomass energy and other renewable energy technologies. While the trend is toward giving these considerations more weight, the process and methods are still controversial and far from being widely used. There is a need to internalize or capture these environmental benefits

6. MTBE Phase Out Issues

In addition to California's electricity system, biomass resources can have a significant impact on resolving issues confronting California's transportation sector. In response to public health concerns, Governor Davis issued an Executive Order in March of 1999 requiring phase out of methyl tertiary-butyl ether (MTBE), an oxygenate gasoline additive from gasoline sold in California by no later than December 31, 2002. Phase out of MTBE will result in an increased demand for other oxygenates, with the most likely substitute being ethanol. A consequence of the phase out is an increase in-state ethanol demand from the current level of 150 million gallons per year up to as much as 1.15 billion gallons per year. Presently, California generates only 6 million gallons per year of ethanol. Within his Executive Order, Governor Davis called upon the Energy

Commission to investigate the potential for development of a California waste-based or other biomass-based ethanol industry. Development of a cost-competitive biomass-based ethanol industry is possible, but only with advances in technology and support from state agencies that have oversight authority over biomass conversion facilities.

D. Public Health and Safety

Concurrent with its electricity system problems, California also faces a number of public health problems related to management of its biomass resources. In particular, California wildfires burn approximately 130,000 acres of forestlands every year, producing over 600,000 tons of air pollution and costing Californians over $1 billion in fire fighting and property damage costs. In addition, present day California solid waste management, agricultural and forestry practices annually generate over 60 million tons of biomass residues. While many of these residues are disked back into the soil or developed into useful products, many more are burned in piles on farmland or on forest slopes, or disposed of in landfills. In the mid-1990's, over seven million tons per year of California biomass residues were used in biomass power plants. Today, California's biomass power plants use less than five million tons of biomass residues. Different methods for managing California's biomass resources, including increasing their use as a renewable fuel are needed to resolve these significant environmental and public health issues.

E. Institutional: Conflicting Regulations and Lack of Coordination among Jurisdictional Agencies

Series of conflicting regulations that leave them few realistic options for dealing with disposal or use of biomass residues besets biomass generators, processors and end users. As indicated earlier, the agricultural community is facing increasing pressure to eliminate open-field burning. At the same time, landfills are confronted with recycling mandates that discourage their acceptance of agricultural residues.

The forestry industry is caught in a similar clash of regulations. On one hand, wildfire prevention regulations encourage thinning operations that will result in removal of harvested trees. However, environmental concerns regarding thinning operations have led to a series of restrictive regulations on timber sales. As a result, it is often five to seven years before a timber sale can receive all the approvals and begin thinning operations. In addition, low cost bids on timber sales often culminate in thinning operations that leave slash piles to be burned or removed in some other manner.

Like agricultural communities, California urban interfaces are also caught in conflicting regulations involving landfills. State law requires that municipalities divert fifty percent of their wastes from January 1, 2000. The same law provides only ten percent credit to those wastes that are diverted to "transformation facilities", such as biomass power plants. As a result, of the nearly 5 million tons of urban wood wastes generated each year, diversion of these residues to biomass power plants would provide California municipalities with diversion credit for only 500,000 tons.

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Management of California biomass resources cuts across a number of state agencies. Consequently, resolving problems associated with California biomass requires coordination among state agencies. While sometimes connected, current State approaches are not well integrated or coordinated. This makes it difficult to: evaluate the overall effectiveness of state programs; to achieve possible efficiencies in research and governmental policies to avoid conflicting regulations; to maximize participation by the private sector; and to best leverage cost sharing or use of State Agency resources and federal funds.

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V. Biomass RD&D Issues and Role of PIER

The CEC is interested in supporting biomass energy research projects that help make California's electricity cleaner, more affordable, safer, and ultimately more reliable. As indicated in Section III, properly harnessed biomass resources can provide tremendous benefits to the state. Biomass generated electricity is already providing widespread benefits to Californians, including energy, environmental, and societal benefits. Biomass to electricity generation and co-production of value-added products (or creation of biorefinery co-production of power, ethanol and other chemicals) could potentially lead to a lower cost of electricity for California consumers. Biomass to energy production may provide additional positive externalities, such as a means of disposing biomass residues, improved air and water quality, and progress toward a renewable and more sustainable energy base. In addition, electricity derived from biomass and other renewable resources already provides several benefits to California's electricity customers, including but not limited to enhanced electrical system diversity, improved air quality, and increased local and state tax revenues and employment. Consequently, PIER efforts in the biomass energy area will focus primarily on the following targeted objectives:

- Research, development and demonstration activities that will promote the diversions of agricultural residues from open burning, urban wood waste from landfill disposal and pursuit of forest-treatment operations in order to reduce risk of wildfires.
- Research, development and demonstration activities that will make existing biomass to electricity more competitive or affordable in a deregulated electricity marketplace while capturing and improving current benefits.
- Develop and demonstrate new biomass based energy conversion systems capable of providing sustained, add revenue streams or increase benefits to California's electricity customers.
- Expand the affordability and cost competitiveness of biomass by developing and demonstrating distributed generation systems that can help provide electricity to meet peak demands and electricity in high congestion, high demand areas while diversifying the electricity system and improving its reliability and dispatchability.

As discussed previously, a number of issues confront the development of more competitive biomass energy conversion technologies. Some issues, such as more affordable financing and resolve conflicting regulations and other institutional barriers are beyond the realm of PIER sponsored research, development, and demonstration activities. However, improving affordability and cost-competitiveness, improve efficiency, reduce biomass fuel costs, improve environmental quality, lowering capital and O&M costs, improving reliability, and increasing dispatchability are among the activities appropriate to PIER RD&D efforts.

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A. RD&D Issues Addressed by Non-PIER Resources

A number of public and private sector parties are actively involved in biomass to energy RD&D. A plethora of federal, state and local government agencies actively participate directly and indirectly in the biomass to energy field. The most active federal government players are the Department of Energy (DOE), DOE's National Renewable Energy Laboratory (NREL), Sandia National Laboratory and the United States Department of Agriculture (USDA). Likewise, other state energy offices, academic institutions and research agencies are involved in biomass energy development and demonstration activities.

The specific RD&D issues address by non-PIER resources are discussed below:

1. National Bioenergy Initiative

Keen interest in bioenergy is being demonstrated by the federal government and other sectors leading the world in the level of investments in RD&D for biomass. The Biomass Initiative is the multi-agency effort to coordinate and accelerate all Federal biobased products and bioenergy research and development. The Initiative was first formed in August 1999 under the Executive Order 13134: Developing and Promoting Biobased Products and Bioenergy with additional guidance given in an accompanying Executive Memorandum. The Initiative is managed by the National Coordination Office (NCO), and is staffed with personnel from the Department of Energy and the United States Department of Agriculture. The NCO also administers the Biomass Research and Development Board, which is responsible for the coordination of all Federal activities for the purpose of promoting the use of biobased industrial products. The member federal agencies are listed below:

- United States Department of Agriculture
- Department of Commerce
- Department of Energy
- Department of the Interior
- Environmental Protection Agency
- Office of Management and Budget
- National Science Foundation

Road maps are being formulated and will be implemented nationwide as a response to President Clinton's Executive Order.

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2. Thermochemical Energy Conversion RD&D Issues Being Addressed by Non PIER Resources

a. DOE/NREL Biopower Program

The U.S. DOE/NREL Biopower Program is working to meet our national energy needs, and simultaneously reduce conventional energy dependence, protect our environment, and improve our rural economy. The Biopower Program represents a program-wide effort to articulate the key issues related to the expanded development and utilization of biomass for power production, mainly thermochemical conversion systems, and defines the roles of the federal government and U.S. industry in partnering to accomplish the strategic goals. The three overarching goals of the Biopower Program are: a) establish partnerships with industry, b) encourage the highest standard of environmental stewardship, c) enhance economic development opportunities.

The Department's Biopower program concentrates on research with commitment to near-term, mid-term, and long-term R&D with a single strategy focus that provides a uniform and integrated program. Biomass power R&D are being done at four DOE's laboratories. These laboratories are: the National Renewable Energy Laboratory (NREL), Oak Ridge National Laboratory (ORNL), and National Energy Technology Laboratory (NETL). At present the program focuses on R&D projects including cofiring with coal, gasification, small modular systems, combustion research, and feedstock development.

One of the projects under the Biopower Program is the demonstration of gasifier in Burlington Vermont. The project purpose is to verify design and operating characteristics of the 200 tons of biomass per day system. The demonstration project was put together by a unique partnership that includes Burlington Electric Department, US DOE, Battelle, NREL, and Future Energy Resources Corporation (FERCO). FERCO is a private firm committed to developing and commercializing the gasifier. This project demonstrates a process called low-pressure, indirect gasification biomass. The process mixes wood chips with very hot sand at a temperature of about 830C or 1500F. The hot sand breaks down the wood and helped by added steam, causes the resulting carbon, hydrogen, and oxygen to form combustible gases. The gases and sand leave the gasifier and the gas is cleaned for use as fuel. The fuel gas formed has a heating value of 500 Btu/cubic ft, which qualifies it as a medium Btu gas. Testing is being done to verify its performance. Sustained operation and testing with gas turbine will begin late 2001.

Small Modular Biopower

Working with industry, the U.S. DOE's Small, Modular Systems Project is developing small, efficient, and clean Biopower systems. The project consists of feasibility studies, prototype demonstrations, and proceeding to full system integration based on a business strategy for commercialization.

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Small modular systems have potential applications in both domestic and international markets. They have cost advantages in niche markets because of their modularity, standardized manufacture, and transport. Because they have simple connections, they will require a minimum of field engineering at customer sites. The intended power range for these systems is from 5 kilowatts to 5 megawatts.

Compared to fossil fuel-based small, modular power systems predominating today's markets, biomass provides a more environmentally acceptable alternative. Furthermore, successful commercialization of small Biopower systems completes the development of a Biopower industry covering a range of power applications, including small systems for village power or distributed applications; combined heat and power systems for industrial applications; and cofiring, gasification, and advanced combustion for utility-scale power generation.

The companies and technologies that performed or are doing small modular biopower projects are enumerated below:

Company	**Technology**
Agrielectric Power, Inc. Lake Charles, Louisiana	Fluidized-bed combustion with steam turbine
Bechtel Corporation Gaithersburg, MD	Gasification with spark ignition engine / generator, combustion turbine, or fuel cells
Bioten GP Knoxville, Tennessee	Direct-fired combustion turbine
Carbona Corporation Atlanta, Georgia	Gasification with spark ignition engine generator
Community Power Corporation	Gasification with spark ignition engine / Aurora, CO generator
Energy and Environmental Research Corporation Grand Forks, North Dakota	Fluidized bed combustion with combustion turbine
Niagara Mohawk Power Corporation Syracuse, New York	Gasification with spark ignition engine / generator or combustion turbine
FlexEnergy International Mission Viejo, California	Low-pressure gasification with combustion turbine

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Stirling Thermal Motors Corporation Ann Arbor, Michigan	Gasification with Stirling engine / generator
SunPower, Inc. Athens, Ohio	Gasification with Stirling engine / generator

Phase I of the above projects have been completed. Phase II will be the actual development and demonstration. Two of the Phase II winners; namely, FlexEnergy Inc. and Community Power Corporation are now being co-funded through the PIER program, with an aim of providing benefits to California.

NREL's Thermochemical Users Facility offers researchers a small-scale facility (0.1 kg/hour to 20 kg/hour) capable of handling to test new equipment and processes for converting all types of biomass feedstocks into high-value chemicals, transportation fuels, and electricity. Research takes place on all aspects of biomass. Special capabilities include different types of reactors, gas conditioning and instrumentation such as spectrometers for analyses of chemical constituents during reaction.

Oak Ridge National Laboratory provides technical leadership and field management for the **Bioenergy Feedstock Development Program**. The program began energy crop research in 1978 and now supports research on: fast growing trees, grasses (herbaceous crops), environmental implications, and resource analyses and economic assessments.

Sandia's Combustion Research Facility's Multi-Fuel Combustor Laboratory is a basic research laboratory with unique capabilities in laser-based diagnostics of reacting flows resulting from combustion of different fuels, including biomass. Research in the biomass area focuses on modeling and optimizing combustion kinetics for cofiring with coal. This bench-scale laboratory is just large enough to simulate the turbulent flame reaction of cofiring combustion in large-scale power boilers.

National Energy Technology Laboratory (NETL) (formerly the Federal Energy Technology Center (FETC)) implements DOE's Fossil Energy research and development programs. NETL researchers focus their work on cofiring biomass with coal in cooperative R&D projects with industry organizations. In addition, they manage DOE's participation in EPRI sponsored cofiring demonstrations at U.S. utility-owned power plants.

b. DOE/Biofuel Program

The US DOE's National Biofuel Program through the Office of Fuels Development aims to realize the large-scale use of environmentally sound, cost-competitive, biomass-based transportation fuels such as ethanol or bioethanol and biodiesel through the adoption and commercialization of the best technologies. The Biofuels Program together with National Renewable Energy Lab partner with researchers at other national laboratories,

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universities, and industries to use state-of-the-art facilities to carry out biofuels research, development, and deployment efforts.

The Biofuels Program is providing technical and financial support for research, development, demonstration, and deployment of biomass-based, environmentally sound, cost-competitive U.S. technologies to develop clean fuels for transportation, leading to the establishment of a major biofuels industry such as ethanol. To meet these ends, the Biofuel Program is focusing on: the research and development of integrated biofuels systems; the creation of strategic partnerships with U.S. industry and other stakeholders; and improving the operations of the program through well-defined metrics, communication, and coordination with our stakeholders and customers.

c. DOE's Regional Biomass Energy Program

The goal of the Regional Biomass Energy Program (RBEP) is to increase the production and use of biomass energy resources in transportation and other energy-related areas. Five regional offices work with state energy offices and other local partners to identify and facilitate local biomass-related partnerships, coordinate educational workshops, disseminate information, and engage in other activities to promote the production and use of biomass energy. The RBEP seeks to:

- Improve state, local government, and industry capabilities and effectiveness in producing and using biomass energy resources
- Support planning efforts, particularly in assessing resource availability, utilization, and applied research needs
- Encourage economic development through public and private investment in biomass energy technologies
- Perform applied research and engage in cost-shared projects to demonstrate the application of biomass energy technologies
- Reduce or eliminate market barriers, understand economic and environmental costs and risks, and accelerate market acceptance of biomass energy technologies.

3. Biochemical Energy Conversion

a. Anaerobic Digestion of Livestock Manure and other Biomass Fuels

U.S. EPA AgSTAR Program

The Clinton administration's *Climate Change Action Plan*, released in 1993, announced that there would be support for developing voluntary pollution prevention programs to stabilize greenhouse gas emissions to 1990 levels. One initiative to evolve from this decision was creation of the AgSTAR program within EPA and the U.S. Department of Agriculture (in cooperation with the DOE) to provide information, tools and training designed to help farmers make informed decisions about on-farm methane recovery. AgSTAR helps interested participants determine if anaerobic digestion makes sense for their operation. A computer software package called "FarmWare," for instance, provides

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a means of surveying potential sites, assessing energy options and applications, and selecting the most profitable installation. The AgSTAR Handbook, to be finalized in 1997, will complement the software by providing a comprehensive method to developing biogas systems at commercial farms. It will address issues such as technical design, odor control, vendor evaluation and financial performance.

New York State Energy & Development Authority (NYSERDA), US EPA, DOE, and EPRI

A project cosponsored by the New York State Energy & Development Authority, the EPA, DOE, and EPRI, developed, demonstrated, and will evaluate a fuel cell power plant running on anaerobic digestion gas. A commercial 200 kW PC25C fuel cell was modified from natural gas to anaerobic digester gas for heat and power generation. A unique feature of the installation is a gas pretreatment unit installed to meet concerns about hydrogen sulfide in the anaerobic digester gas. It was estimated that the hydrogen sulfide concentration never rose above 3 PPM in the cleaned gas.

DOE Regional Biomass Program

Northeast Regional Biomass Program

NYSERDA Selects Bioenergy Projects in Agriculture

In November the NRBP reported on its efforts to help promote bioenergy in the agriculture community in New York State. The NRBP was a sponsor along with the New York Farm Bureau and the New York State Department of Agriculture for a NYSERDA $1.24 million agriculture initiative to help New York Farmers through innovation and new products. Projects related to anaerobic digestion included:

1. Matlink Dairy Farm, Inc., anaerobic digestion and power generation;
2. Cornell University, feasibility of fuel cells for energy conversion on dairy farms;
3. F.A.R.M.E. Institute, Inc., demonstration of anaerobic digester system for biogas fueled micro turbine.

Great Lakes Regional Biomass Program

Iowa On-Farm Methane Energy Recovery Demonstration Project

Iowa Department of Natural Resources, with assistance from the Great Lakes RBEP, has worked with public and private sector partners to install and operate a manure digester and a biogas boiler at the 2,800-head, swine finishing facility at the Steve and Audrey Crawford Farm near Nevada, Iowa. The Crawford Farm demonstration involved two phases of activity. During Phase I, project partners installed an anaerobic sequencing batch reactor (ASBR) at the demonstration site. In Phase II, project partners installed a biogas boiler to allow methane produced during digestion to be used to raise the temperature of the ASBR and provide heat for the swine production facility. A 950,000-

BTU, used Kewanee biogas boiler to provide heat for the ASBR, swine confinement buildings, and, potentially, for crop drying or other heating needs at the Crawford Farm. An engine generator or another conversion technology may be installed at some future point. Biogas production at the Crawford Farm ranges from 32,000 to 40,000 cubic feet per day. The methane content of the biogas is approximately 70 percent. The equivalent BTU value for the biogas produced is 20 to 25 million BTU (MBTU) per day. At $2.80 per MBTU, the value of 25 MBTU is $70. The value of energy recovery at the Crawford Farm is potentially $70 per day or about $2,100 per month. Methane recovery demonstration activities will continue at the Crawford Farm through September 30, 2001. Activities during this period will include tours and field days, publicity, and presentations.

Pacific Northwest and Alaska Regional Bioenergy Program

Idaho Livestock Industry Anaerobic Digestion Initiative

On February 15 the Idaho Energy Division launched the Idaho Livestock Industry Anaerobic Digestion Initiative at the Idaho Dairymen Councils semi-annual meeting. Over the past several years the number of dairies in Idaho has increased substantially. While this growth has established the dairy industry as an important aspect of Idaho's economy, it has also increased the scope of public awareness and scrutiny of the industry. As a result, there has been pressure from an array of sources calling for improved management regulations on Idaho's dairies. The Energy Division will act as lead in the creation of an Idaho Livestock Industry Anaerobic Digestion Initiative that seeks to install a unique anaerobic digestion process that holds the greatest promise towards resolving the dairy waste issue. The long-range goal of this initiative is the installation of five anaerobic digestion facilities at Idaho dairies by 2005.

Fuel Cell Operating at Columbia Boulevard WWTP

The City of Portland's Bureau of Environmental Services (BES) has released a final technical report on the installation of a fuel cell at the Columbia Boulevard Wastewater Treatment Plant. The phosphoric acid fuel cell manufactured by ONSI Corporation runs on wastewater treatment digester gas. The Oregon Office of Energy, through its bioenergy program, provided funding for design and engineering of the gas-processing unit. Gas scrubbing is necessary to eliminate impurities in the digester gas, principally hydrogen sulfide. The Office of Energy also provided a $175,000 tax credit, which enabled the project's financing. The fuel cell became operational in July 1999. It has been generating a net output of 175 kilowatts. Waste heat from the fuel cell is recovered and used to heat the digesters. BES estimates that the fuel cell reduces the treatment plant's annual electricity bill by $92,000. The power generated on site by the fuel cell eliminated the need for emergency generators, thereby saving an additional $150,000. BES estimates that by offsetting the need to purchase power generated from fossil fuel sources, the fuel cell will avoid 14,000 tons of carbon dioxide emissions over the 20-year life of the system. The prototype fuel cell system, which is only the fourth of its kind in the world, had a total cost of $1.3 million.

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Cyclus Envirosystems Submits Proposal for Developing Microturbines

Washington State University (Regional Biomass Energy Program) is working with Dennis Burke of Cyclus Envirosystems and Capstone Turbine to submit a proposal to DOE in response to their "Initiative on Cooperative Programs." The project would install two 30-kW microturbines at the SW Suburban Sewer District Salmon Creek facility. SW Suburban is interested in installing a pasteurization system to complete the work that Dennis began with them. Adding the microturbines would further enhance the overall system advantages for a wastewater facility. Matching funds would come from SW Suburban and Capstone.

b. Landfill Gas to Energy (LFGTE) Recovery System

U.S. Environmental Protection Agency – U.S. EPA (***http://www.epa.gov/lmop/***)

U.S. EPA launched a program called Landfill Methane Outreach Program (LMOP) in 1994. The LMOP promotes landfill gas as an important local energy resource. The LMOP currently has 222 allies and partners that have signed voluntary agreements to work with EPA to develop cost-effective LFGTE projects, including every major landfill gas project development company. The Energy Commission together with other California State agencies just joined as allies LMOP.

The LMOP has developed profiles for over 1,300 candidate landfills in 31 states. There are over 270 operational LFGTE projects in the United States. In addition, approximately 60 projects are currently under construction and at least another 95 are exploring development options and opportunities. To date, the LMOP has assisted in the development of over 120 landfill gas utilization projects – 49 projects in 1998 alone.[3]

*U.S. Department of Energy – U.S. DOE (**http://www.doe.gov/**)*

There are three U.S. Department of Energy (DOE) programs with the objective of encouraging the development of LFGTE projects.

- Research, Development, and Demonstration (RD&D) Program—Part of the Climate Change Action Plan, which targets the technical barriers to landfill methane energy recovery.

- Climate Challenge—A DOE initiative in which utilities agree to achieve greenhouse gas reductions in a way that makes sense for them.

[3] Information is available at: *http://www.epa.gov/lmop/about.htm*.

➢ Voluntary Reporting—A DOE program in which utilities are eligible to report methane reductions from the landfill energy recovery project.[4]

U.S. Energy Secretary Bill Richardson recently announced two initiatives to expand partnerships with state energy offices and energy research organizations. Under the initiatives, the Department of Energy (DOE) will fund about $6 million in cooperative agreements with state agencies for energy efficiency research, development, and demonstration projects in the year of 2000. The DOE has developed model agreements that will streamline the startup of cooperative research between DOE's national laboratories and state energy research organizations, such as the California Energy Commission, an LMOP State Ally.[5]

EPRI (http://www.epri.com/)

Landfill gas, which consists of mostly methane and carbon dioxide in approximately equal amounts, can be a low-cost fuel for power generation. There are, however, contaminants in the landfill gas that are corrosive or otherwise deleterious to power. EPRI developed a low-cost cleanup system that would enable landfill gas to be used in carbonate fuel cells or other power generation devices. The EPRI-developed system is now available for license to commercial applications.[6]

GRI (www.gri.org)

A cofiring system designed by Energy and Environmental Research Corp. will be installed at a Columbus, Ohio power plant to generate electricity by burning landfill gas with solid waste. A GRI project will investigate the potential of natural gas cofiring to reduce plant operational problems and toxic emissions. The project will:

* Providing a gas startup system that is easily controlled and virtually smokeless. The current cold startup practice, using oil-soaked rags and wooden pallets to ignite the coal, produces smoke and are difficult to control.
* Reducing the boiler output fluctuations to as low as 5 percent. Because of variations in the feed rates and composition of refuse, the boilers are subject to output fluctuations of as much as 30 percent.
* Allowing landfill gas to be co-incinerated with solid waste. Landfill gas is currently being flared, ignoring the potential value of the gas to generate energy. Natural gas cofiring could help provide stable, efficient incineration of landfill gas while ensuring that the unit is capable of following the load demand.

[4] Information is available at: **http://www.eia.doe.gov/cneaf/solar.renewables/renewable.energy.annual/chap10.html.**
[5] Information is available at: http://www.epa.gov/lmop/whatsnew.htm#1.
[6] Information is available at: http://www.epri.com/OrderableitemDesc.asp?product_id=TR-108043-V1&targetnid=207869&value=00T023.0&marketnid=207812&searchdate=4/15/97.

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California Integrated Waste Management Board – CIWMB (www. ciwmb.ca.gov)

The CIMWB generates database for landfill sites in California, including sites, enforcement agencies, operators, landowners, capacity, acreage, permit date, waste types, regulatory status and operational status. The database also includes a description of each of the data fields.

California Integrated Waste Management Board has supported the Yolo County Landfill a $400,000 grant for a second and larger fully operational bioreactor landfill demonstration project in 2000. The bioreactor landfill is new solid waste landfill technology that will change the way conventional landfills are operated.

Renewable Resources Trust Fund Program - California Energy Commission

Twenty landfill gas projects are currently participating in the New Account of the Renewables Resources Trust Fund, and by the end of the five-year funding period (Jan.1, 2007), they will have received a total of $28.3 million in funding. Currently, seven of the 22 landfill's gas projects are on-line and receiving funding from the New Account. The Existing Account provides a total of $243 million funding to existing renewable energy projects (built before September 1996). As of February 2000, landfill gas projects participating in the Existing Account have received a total of $2.18 million in funding. It is not certain yet how much funding landfill gas projects participating in the Existing Account will receive by the end of the funding period. This program is being extended for another 10 years, up to 2012.

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c. Biomass to Ethanol (Fermentation)

The entities and entrepreneurs that maintain some involvement in biomass to ethanol in California have been the following groups: BCI Corporation and Arkenol Corporation. This is by no means an exhaustive or comprehensive list of all the entities involved in biomass to ethanol. Rather, the intent of this selection of institutions and entities is meant to demonstrate the level of interest in the biomass to ethanol area. Finally, the aforementioned highlights those individuals looking to actively merge electricity production with bio-products manufacture.

Apart from the California Energy Commission, the most active state players in biomass to energy have been the New York State Energy Research and Development Agency (NYSERDA) and the Governor's Ethanol Coalition.

DOE/NREL Biofuels (Ethanol) Program

The Department of Energy (DOE) through its National Renewable Energy Laboratory (NREL) helps lead the national effort to develop technologies in tapping the enormous potential of lignocellulosic biomass to ethanol. NREL seeks to develop cost effective, environmentally friendly technologies for converting biomass to fuels fuel additives and chemicals. In the short run, NREL foresees the use of low-cost biomass residues for the production of value-added, bio-based products. Over the longer term, NREL expects to shift to dedicated energy crops for fuels production. In addition to its focus on bioethanol, NREL also has ongoing projects on biodiesel production. In a collaborative partnership with universities and industry, NREL currently supports the following four technology platforms:

- Concentrated Acid Hydrolysis
- Dilute Acid Hydrolysis
- Enzymatic Hydrolysis
- Biomass Gasification and Fermentation

In addition, DOE also work with other laboratories including Oak Ridge National Lab and Tennessee Valley Authority. NREL, through its collaborative partnerships also facilitates research into the following critical areas of biomass to ethanol technology:

- Feedstock Composition and Properties
- Cellulase Enzyme Research
- Dilute Acid Hydrolysis and Pretreatment
- Fermentation Organism Research
- Lignin Derived Co-products
- Softwood Conversion

The biomass to ethanol projects supported by DOE Biofuels program are discussed below:

BC International Jennings, Louisiana Project

Very soon, the first facility in the world to produce ethanol from sugarcane wastes and rice hulls will open. In October 1998, BC International, a startup technology company, dedicated a former molasses-to-ethanol plant in Jennings, Louisiana. NREL engineers have helped this project proceed by performing, at a pilot scale, fermentation with BCI's recombinant organisms, and have verified pretreatment performance on a variety of feedstock. DOE has invested $11 million toward the renovation of the facility, which will produce 20 million gallons of ethanol per year initially; its long-term annual goal is 25 million gallons. Most of the ethanol will be used as an industrial solvent; some will likely also be used to fuel cars. The biomass ethanol process creates a residue that contains mostly lignin, which is very combustible. It will be used to generate electricity and provide raw materials for the chemical industry. The $90 million facility will create 350 construction jobs and 50 permanent jobs and displace almost 500,000 barrels of imported oil annually.

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The primary goals of the project are to successfully demonstrate ethanol production from agricultural residues and help lower the cost of cellulase enzymes so ethanol can be produced from agricultural residues and energy crops at lower costs and higher efficiencies.
BC International

BC International Gridley Ethanol project

The BC International Corporation's second commercial facility for manufacturing ethanol from rice straw and wood feedstock (mainly orchard residues) will be located in Gridley, California. The site will be located next to the Pacific Oroville Power Inc. (POPI) Plant, an 18.5 MW biomass power facility. Locating BCI's facility at this site will reduce costs and improve efficiencies of the power plant as well as proposed ethanol facility. DOE provides $12.5 million to BC International and Rice Straw Cooperative towards the development of the new Gridley facility. California Energy Commission provided $160,000. This co-located ethanol plant will produce 20 million gallons of ethanol annually, while also providing a creative solution to the rice waste disposal problem in Sacramento Valley. This co-located facility is expected to generate about 350 construction jobs and employ 60 full time personnel. The project will create tax base and foster economic improvements in the region. The project will also improve air quality by reducing power plant emissions, greenhouse gases, and open field burning of rice straw, and by creating ethanol – a clean transportation fuel. The lignin byproduct from ethanol production will be used as boiler fuel for the 18.5 MW biomass power plant at POPI.

Masada Resource Group Orange County, New York, Ethanol Project

Masada Resource Group, based in Birmingham, Alabama, is developing a $130 million waste disposal and recycling facility in Middletown, New York. On the front end, it will recycle plastics, glass, metal, and wastepaper. The plant will also use technology developed in partnership with Tennessee Valley Authority and DOE to convert the remaining cellulosic refuse into 8 million gallons of ethanol annually. The facility is planned for startup in the year 2000. This is the first proposed biomass ethanol plant to use MSW as a feedstock. NREL researchers reviewed the process and supplied technical support, and DOE has provided $2 million to support the project.

Masada has negotiated contracts with the surrounding municipalities to accept their MSW, and the municipalities will share in the profits. This waste, which would otherwise be burned or landfilled, will be used to domestically produce a clean-burning renewable fuel that will displace almost 200,000 barrels of imported oil annually.
Masada

Sacramento Ethanol Partners Facility Project
During 1999, Arkenol, a technology company based in Mission Viejo, California, plans to begin building a new biomass-to-ethanol plant near Sacramento, California. The $100

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million facility will produce 8 million gallons per year of fuel ethanol from rice straw. It may also produce citric acid. Key engineering, permitting, and financing activities are under way through a partnership with DOE, which has committed $4 million.
This project provides a much-needed alternative to rice straw burning, which is being phased out in California for environmental reasons. This will be the first facility in the world to use rice straw to produce ethanol and citric acid on a commercial scale, and it will help will solve the problem of rice straw's high silica content by producing precipitated silica. It will create about 200 construction jobs and 105 permanent jobs.
Arkenol

Activities of Other States on ethanol

Governor's Ethanol Coalition. The Governor's Ethanol Coalition is a powerful interstate, and more recently, international group, which lends strong support to domestic corn and grain, based ethanol production. The group was formed in 1991 under the leadership of the Governor of Nebraska. Since that time, the GEC has grown from its initial nine member states to twenty-eight participants- twenty-three primarily Midwestern states and five international members (Canada, Sweden, Mexico, Puerto Rico, and Brazil). In addition, each of the member states or countries provides some sort of assistance and/or financial incentive for the production of ethanol within its borders. The notable examples of individual states giving incentives for ethanol production are Hawaii, Wisconsin, and Missouri. The GEC, headquartered in Lincoln, Nebraska, has as one of its goals the desire to make that ethanol and its derivative, ETBE, have a role in the nation's transportation fuels market. The ultimate goals of the GEC are to increase the use of ethanol based fuels, decrease the nation's dependence on imported energy resources, and improve the environment and simultaneously stimulate the national economy. The GEC represents the most serious challenge to a lignocellulose to ethanol industry in California, and wields considerable influence in the direction of the biorefinery concept in California.

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New York State Energy Research and Development Agency (NYSERDA). NYSERDA has been actively involved in lignocellulose to ethanol research for over a decade. NYSERDA has previously funded research into a variety of topics relating to biomass to ethanol, such as the cultivation and use of specific energy crops, ethanol fermentation with exotic microorganisms, and thermotolerant cellulase research. NYSERDA continues to maintain an active role in the lignocellulose to ethanol field.

Key State Level Players in Biomass to Ethanol

The following is a brief summary of some of the more active players in the California biomass to ethanol scene:

SEPCO-Arkenol. A joint partnership by Arkenol and SMUD will use concentrated acid hydrolysis technology to produce ethanol from rice straw in the Sacramento valley area. Arkenol plans to recover citric acid and silica from the rice straw as co-products.

Masada Resoure Group. The Masada operation intends to produce ethanol from municipal solid waste in Orange county, California. They too will use a concentrated acid hydrolysis process, and plan to recover gypsum and carbon dioxide as co-products.

BC International (BCI). BCI has three ongoing projects to produce ethanol from biomass. Two of these projects are located in California, while a third, being done in partnership with the DOE, is in Jennings, Louisiana and uses sugarcane bagasse as its feedstock. All of their projects will utilize two stage dilute acid technology. BCI is also making allowances for the use of enzyme based hydrolysis, in combination with dilute acid methods, should the technology ever become cost-effective. One of their California projects, located in Gridley, will use a combination of rice straw and wood wastes as the feedstock. This project is both noteworthy and unusual because it will be collocated to an existing biomass to electricity facility operated on-site by the Pacific Oroville Power Plant. BCI also plans to operate another collocated ethanol facility with Collins Pine in Chester California. This plant is slated to use softwoods as a feedstock, and will treat them with dilute sulfuric acid followed by enzymatic hydrolysis with proprietary bacterial enzymes. In this facility, BCI hopes to convert the extractives in the softwoods to two to three chemical co-products and hopefully launch California's first forest biomass refinery.

Tembec-Georgia Pacific. This undertaking by Georgia Pacific seeks to capitalize on its sulfite pulp mill operations and use dilute acid hydrolysis to dissolve hemicellulose and lignin to yield high grade cellulose pulp. They ferment the hexose sugars in the spent sulfite stream to ethanol, and either burn the lignin to create energy or use it to make higher value added products such as dispersing agents or animal feed.

4. California State Interagency Biomass Initiative

Management of biomass resources cuts across a number of California State agencies. It is a major and growing problem for California and administration. Consequently, resolving the problems associated with California biomass resources requires coordination among state agencies. While sometimes connected, current state approaches to biomass resource management are not well integrated or coordinated.

In consultation with industry, local governments and other interest, the interagency working group was established to develop multi-agency program to transform biomass residues and waste into productive uses. This interagency working group was established in June 1999. It is operating under the joint direction of the (signed MOU):

Secretary for Environmental Protection
Secretary for Resources
Secretary of the Department of Food and Agriculture
Secretary of Trade and Commerce

It includes representatives from**:**

Air Resources Board
California Energy Commission

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Department of Food and Agriculture
Department of Forestry and Fire Protection
Integrated Waste Management Board
Trade and Commerce

The goals of the interagency working group are:

- Encourage and support diversion of residues and wastes to productive uses
- Improve environmental quality and public safety
- Strengthen the State's economy, especially in rural areas of highest unemployment
- Emphasize market-based policy options and flexible tools for businesses and government agencies involved in biomass management
- Provide for state-of-the art governing structure that encourage creativity, technological innovation, industry and public participation, and supportive economic and regulatory framework, and
- Develop an integrated and rational biomass policies

B. Coordination with California Energy Commission Programs

PIER serves to promote and conduct energy research in the public interest that will lead to a lower cost of electrical energy, an improved quality of life, and environmentally sound, safe and reliable energy sources and products for California consumers. Biomass to energy may provide an improved environmental outlook for the state while at the same time providing other value added products such as ethanol as a source of cleaner burning transportation fuel.

In order to provide these perceived benefits, PIER sponsored research must ultimately move out of the research arena and into the commercial marketplace. Historically, research products have a difficult time moving from the research phase into the marketplace due to the lack of funding. However, support is potentially available to biomass energy conversion facilities under the Energy Commission New Renewable Resources Program, and other PIER-specific programs. In order to help biomass facility operators and developers maneuver their way from research to the marketplace, PIER program staff work closely with Renewable Energy program staff in developing complementary goals and objectives. Similarly, the PIER Renewable Energy Program collaborates with the PIER Small Energy Innovations Program to ensure proof of concept projects coordinate appropriately into PIER program goals.

C. Appropriate PIER Efforts

The specific targeted goals for PIER biomass RD&D that address the issues outlined in Section IV while maintaining and increasing benefits for California's electricity system are discussed below.

PIER biomass RD&D efforts will have four areas of focus.

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First, PIER will target and prioritize those research areas that will make biomass to electricity generation facilities to be more responsive to the deregulated marketplace. Primarily conducting market assessments to determine the market needs and economics of thermochemical and biochemical biomass energy conversion technologies will achieve this. And to perform strategic value analyses to determine how biomass to energy facilities can add the greatest amount of value to California as a whole, including electricity production and co-produce value-added products for further economic development, job creation, among others.

Second, PIER RD&D efforts will attempt to make California's biomass industry more competitive in the deregulated electricity marketplace. This will be achieved in part with a strong emphasis towards developing improvements for use at existing biomass electricity generation facilities. Improvements at existing biomass electricity generators should result to electricity that is either less expensive than other competing alternatives or represent an increased supply of electricity to high demand areas that cannot be provided by other means. Improvements at existing biomass facilities can be geared towards providing increased system reliability and dispatchability and increasing peak generating supplies and or develop value-added products that has high value to the region or customer class. Improvements could include reducing capital and O&M costs, reducing fuel cost, increasing efficiencies, and accelerating the development of co-located biomass to ethanol technologies to existing biomass power plants.

Targeted efforts should be done to encourage the diversion of agricultural residues from open field burning, promote the diversion of organic waste (i.e., urban wood waste) from landfill disposal, promote the pursuit of forest treatment operations in order to reduce the risks of wildfires and enhance watershed and ecosystem health throughout the State. Furthermore, promote the development and demonstration of anaerobic digestion facilities using livestock manure or waste water or sludge and use of landfill gas recovery systems.

Third, biomass PIER RD&D effort will attempt to advance the development and demonstration biomass-fueled distributed generation systems, such as small modular biomass energy conversion systems. The systems can be located close to demand centers and close to available feedstock supply. Similarly research efforts should be focused on areas in the state with high level of congestion or reliability problems may help defer expanding or upgrading T&D capacities and help provide clean, renewable, reliable and cost competitive electricity.

Fourth, for the long term development, RD&D efforts of biomass energy conversion systems should try to attempt to develop advanced biomass energy conversion systems that can provide electricity with high value or more cost competitive and integrated to capture environmental benefits and co-produce other higher value products. This could include development of integrated biorefinery in which biomass plants are closely tied to other industrial facilities that supply fuel and purchase steam or electricity and produce byproducts or other value-added products.

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These RD&D activities could be achieved by leveraging the efforts of other funding agencies, such as the DOE, in this regard.

1. Market and Benefits Assessments

The purpose of these projects will be to determine the current, near-term and or long term needs for biomass to energy conversion strategy in California's deregulated electricity marketplace. In summary, market assessments and technical feasibility studies will:

- Identify what changes will be necessary in biomass energy conversion technologies to make biomass energy responsive to a deregulated marketplace
- Characterize biomass technologies that will be most likely to be successful under a deregulated markets
- Identify the potential for biomass development in California and evaluate the deployment opportunities for biomass energy technology
- Identify the demands and requirements of biomass energy technology in order to effectively target further research areas

More specific market assessment and technical feasibility studies include:

- California biomass technologies (direct combustion, thermal gasification, anaerobic digestion, LFGTE and biomass to ethanol) and benefits assessment. Assess market needs and economics of these technologies.
- Hybrid and distributed generation applications
- Technical and economic feasibility study of the biomass gasification and fermentation process

2. Strategic Value Analysis

Strategic value analysis will help determine the appropriate performance characteristics and best location for biomass to energy conversion facilities and other renewable energy technologies. This analysis will provide strategic value to California's electricity system while simultaneously providing high public benefits.

The strategic value analysis will:

- Identify generation and transmission and distribution problems confronting California's electricity system
- Identify electricity generation performance characteristics needed to address problems
- Identify locations where biomass and other renewable resources that can address "hot spots'
- Identify R&D needed to develop biomass and other renewables to meet required generation performance characteristics
- Produce models that identify how biomass and other renewables can play a strategic role addressing problems facing California's electricity system and provide high public benefits

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- Produce a report that identifies energy R&D needed to develop biomass and other renewables to play strategic role
- Conduct a case study to verify results of models

3. Helping to Make Existing California's Biomass Electricity Industry More Cost Competitive

Reducing the relatively high cost of electricity of biomass energy and increasing its reliability and dispatchability are the primary issues in achieving competitiveness in California's electricity marketplace. Improvements at existing biomass facilities geared towards increasing peak generating supplies or providing increased system reliability can help attenuate spiraling electricity prices. There are several ways in which the cost of electricity can be reduced:

a. Reducing O&M Costs
b. Reducing biomass fuel costs (lowering harvesting, collecting, processing, storage and transporting feedstock to biomass energy conversion facilities)
c. Increasing biomass energy conversion efficiencies
d. Develop value-added products (ethanol, chemicals and other extractives)
e. Cogenerate heat for thermal applications
f. Develop the ability to provide ancillary services
g. Improve reliability and dispatchability or peaking generation capabilities such as developing hybrid systems

4. Help to Advance Biomass-fueled Distributed Generation Systems

RD&D activities for distributed generation using biomass fuels can be located close to demand centers and sustainable feedstock supplies including:

a. Development of biomass energy conversion systems that can match the demand profiles of the demand centers and help defer T&D and provide power quality benefits and VAR support
b. Develop small modular systems close to sustainable fuel supply
c. Develop hybridized systems with superior peaking and load following capabilities
h. Improve reliability and dispatchability
i. Co-produce value added products

5. Develop Advanced and Integrated Biomass Energy Conversion Systems (Small Scale and Large Scale Systems)

RD&D efforts to be included here should provide desirable and more affordable electricity system fueled by biomass and other biomass derived fuels:

a. Establish an integrated biorefinery that co-produce electricity, chemicals and other value added products

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b. Demonstrate and prove performance of small, modular biomass energy conversion systems (AD and LFGTE systems, biomass combustors and gasifiers coupled to microturbines, fuel cells, and Stirling engines)
c. Demonstrate large scale systems such as coupled gasification/combustion systems and integrated gasification systems
d. Demonstrate and prove performance of increase efficiencies of advanced biomass energy conversion systems

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VI. PIER Biomass RD&D Strategies

Biomass energy offers distinctive benefits to California's environment, electrical ratepayer and the public. Many of these benefits, however, are indirect. Biomass to energy may serve as an attractive disposal option for an increasing amount of biomass resources. With increasing demand for electricity, often "on peak" in the year ahead, biomass energy has the potential to meet the needs. In addition, economic and environmental benefits can be captured. At a recent national distributed generation conference, experts predicted that distributed generation would gain momentum and market applications in California starting 2001 to 2005. Biomass to energy can play a significant role in this transformation as a clean, affordable, competitive, reliable energy conversion technology.

Figure 18 and 19 shows the goals and pathways that comprise the strategic approach to be used by PIER Renewables team. Figure 18 shows the cost goals in levelized COE (cents/kWh). COE's for thermochemical and biochemical conversion pathways are estimated to fall within the area of the curves.

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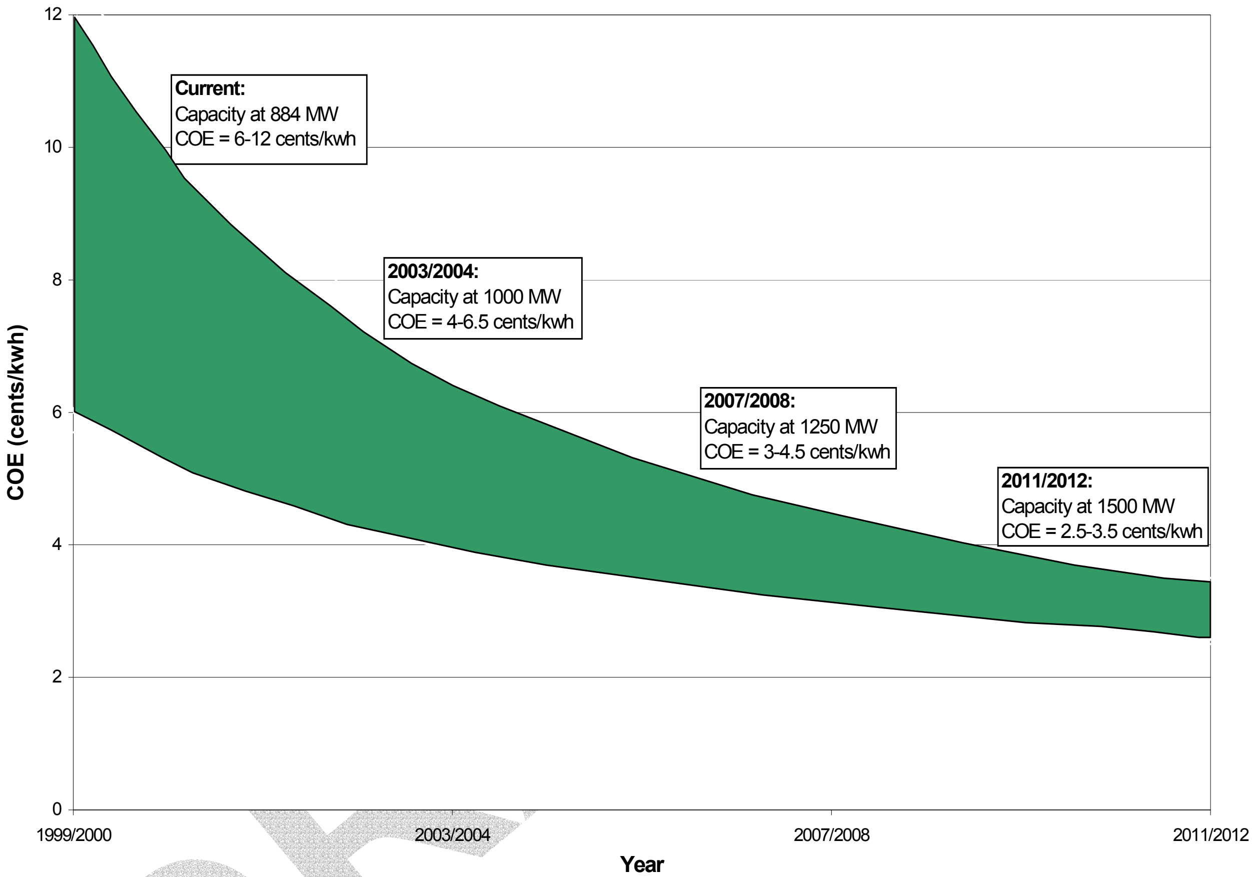

Figure 18. Targeted COE Over Time

Table 8 shows the research plan for PIER biomass energy RD&D efforts. There are three sections in this plan namely; near term (2003/2004), midterm (2007/2008), and long-term (2011/2012) targeted research areas for direct combustion, thermal gasification, anaerobic digestion and landfill gas recovery systems.

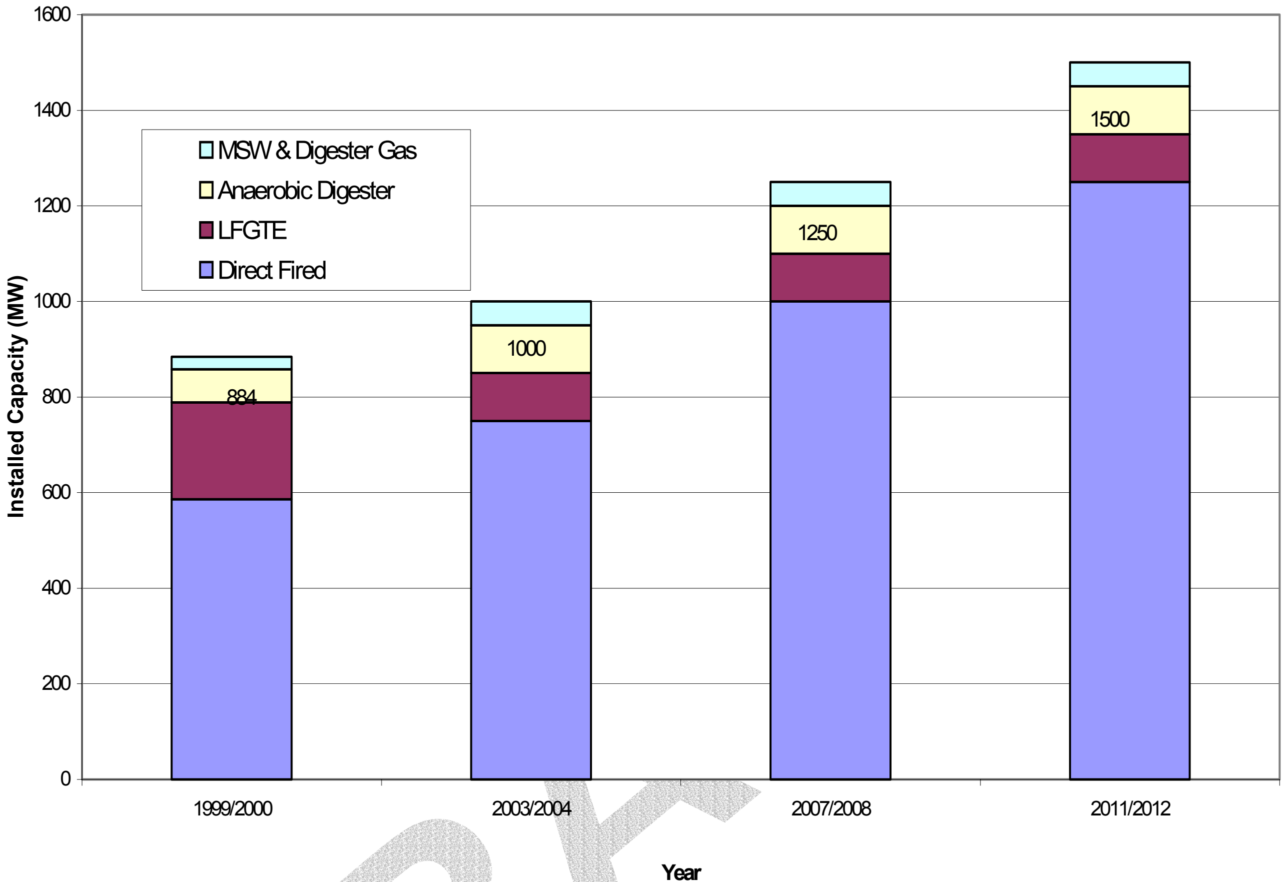

Figure 19. Targeted Increased Capacity Over Time

Table 8: Biomass RD&D Needs and Approaches				
Timeframe /SubArea	***Issues***	***Focus***	***Funding Mechanisms***	***Funding Amount***
1. Existing a. **Direct Combustion**	Not Competitive: – High Costs – High fuel costs – Low efficiencies – Low or not dispatchable – Lack of understanding of marketplace needs and economics in a deregulated	Increase competitiveness in deregulated marketplace by developing techniques or processes that: – reduce costs (capital and O&M costs) – reduce fuel costs – increase efficiency – increase dispatchability	PIER Transition, 1 and 2 Solicitations: • High costs: ➢ EER PIER 2 contract: reducing costs using low value residues • Dispatchability: ➢ GRI PIER 1 contract: increasing	Already encumbered: $2,787k • High costs: ➢ GE-EER: $982k • Dispatchability: ➢ GRI: $656k

Table 8: Biomass RD&D Needs and Approaches				
Timeframe /SubArea	***Issues***	***Focus***	***Funding Mechanisms***	***Funding Amount***
	environment – Lack of understanding of strategic value of biomass in the grid – Lack of non electricity revenue streams	– increase understanding of marketplace needs and economics – Perform strategic value analysis of biomass in the grid – develop value added products	dispatchability using natural gas co-firing in existing biomass boilers (hybrid) • Value added products: ➢ Collins Pine PIER 2 contract: developing ethanol and other value added products from existing biomass power plants Tech Assistance: ➢ Updated assessment of facilities, marketplace economics and needs Sole Source: ➢ Strategic value database and GIS of biomass power **conversion facilities (i.e., biomass power plants, power & co-ethanol production, anaerobic digestion & landfill gas recovery systems)** in distributed generation setting	• Co-production of Value Added Products: ➢ Collins Pine: $1,149k Tech Assistance: ➢ Facilities and marketplace assessments-through EPRI membership ($?) Sole Source: ➢ Strategic value GIS of biomass power conversion facilities ($?)
2. **Near term (2003/2004)** **a. Direct Combustion**	Emerging Competitive: – High Costs – Low efficiencies – Relatively high NOx emissions – Low dispatchability – Reliability of system is threatened during peak periods or not meeting peak demand	Continue efforts to increase competitiveness in deregulated marketplace by developing techniques or processes that: – Reduce costs (capital, O&M and fuel costs) – Increase efficiency	Collaborative agreements: ➢ Begin and continue development of integrated and high efficiency direct combustion systems that use low to zero cost fuels and co-produce higher value added products such	2. Near Term a. Direct Combustion ➢ Continue - Colocated Biomass to ethanol facilities (Collins Pine/Gridley

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Table 8: Biomass RD&D Needs and Approaches				
Timeframe /SubArea	***Issues***	***Focus***	***Funding Mechanisms***	***Funding Amount***
	– Lack of waste disposal options – Lack of non energy revenue streams	– Reduce NOX emissions – Develop and demonstrate co-production of value added products – Improve waste utilization in a cost competitive and environmentally acceptable manner – Develop and demonstrate small distributed generation applications	as ethanol and other extractives. Sole Source: ➢ Demonstrate technical and economic feasibility of using lignin as boiler fuel ➢ Develop and demonstrate techniques or processes that lower costs ➢ Develop and demonstrate techniques or processes that will make biomass direct combustion facilities become affordable in a deregulated market place such coupled combustion/gasification to lower NOX, reduce fuel costs, and co-produce value added products ➢ Develop and demonstrate distributed generation applications	projects) ($1.2 million), Co-fund actual demo Proposed: ($5 million) Sole Source: ➢ Accelerated Lignin Test for biomass power plants (Ogden Power Pacific Inc. $500k) Competetive RFP ➢ Results based from Strategic Value Analysis and PIER 1 and 2 Contracts Proposed: $ TBD Competitive RFP: ➢ Small distributed generation Proposed: $ TBD)
3. Mid Term (2007/2008) **a. Direct Combustion**	Remaining development issues: – High capital and O&M costs – Prove performance of	Continue the development and demonstration of systems that can compete in a deregulated marketplace:	Collaborative or Competitve RFP's: ➢ Develop and demonstrate integrated systems or	**4. Mid Term** **a. Direct Combustion** **Proposed**

Table 8: Biomass RD&D Needs and Approaches				
Timeframe /SubArea	***Issues***	***Focus***	***Funding Mechanisms***	***Funding Amount***
	improvement in efficiencies and cost reduction techniques – Complete integration and hybridization – High emissions compared to natural gas fired systems – Need to demonstrate dispatchability and reliability to meet peaking demands	– Increase efficiency and reliable systems – Lower costs – Lower emissions – Integrated direct combustion system with co- production of value added products (demonstrate biorefinery) – Improve strategic value of biomass power plants to grid	biorefinery Competitive RFPs: ➢ Demonstrate and prove performance distributed generation applications and advanced low emission combustion systems ➢ Develop affordable advanced combustion systems	➢ Integrated or biorefinery development ($ TBD) ➢ Demos of modular and distributed generation applications ($ TBD) ➢ Affordable advanced combustion systems ($ TBD)
4. **Long Term (2011/2012)** **a. Direct Combustion**	Remaining issues: – High costs – Low efficiencies – Lack of performance data for integrated or biorefinery co-production of power, chemicals and other value added products – Need to demonstrate performance or relible, affordable and dispatchable systems	Continue to demonstrate the performance and economics of the high efficiency class direct combustion systems. Demonstrate Integrated biorefinery co-production of power, chemicals and other value added products- and achieve cost competitiveness	Collaborative agreement or competitive RFP: ➢ Demonstrate and obtain tech and economic performance data for integrated biorefinery co-production of power ➢ Obtain performance data of distributed generation applications and advanced combustion systems	4. **Long Term** **a. Direct Combustion** Proposed: ➢ Demos - tech and economic performance of integrated biorefinery (& TBD) ➢ Demos – tech and economic performance of dist gen and advanced systems (& TBD)
1. **Existing** **b. Anaerobic Digestion and Landfill Gas to Energy (LFGTE)**	Not competitive: – High costs – Low efficiency and CH4 recovery – Lack of successful R&D projects – Lack of non electricity revenue streams – High emissions (NOx) for some energy conversion pathways (SI and CI	Increase competitiveness in deregulated marketplace by developing techniques or processes that: – reduce capital and O&M costs – increase efficiency and CH4 recovery – assess of marketplace needs, economics and benefits of AD and	Collaborative and Interagency Efforts: ➢ Assessment and evaluation of potential and opportunities for anaerobic digestion and LFGTE systems (i.e., collaborate with US EPA Landfill Methane Outreach	**Existing** **b. Anaerobic Digestion and Landfill Gas to Energy (LFGTE)** Collaborative and Interagency Efforts: ➢ Potential of Anaerobic digestion and LFGTE

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Table 8: Biomass RD&D Needs and Approaches				
Timeframe /SubArea	***Issues***	***Focus***	***Funding Mechanisms***	***Funding Amount***
	engines and recips) – Ammonia and odor problems (if not recovered in landfill facilities and livestock farm, etc) – Lack of understanding of marketplace needs and economics in a deregulated environment – Lack of information of status and potential for increased use of anaerobic digestion and landfill to gas energy	LFGTE – develop value added products – reduce emissions (NOx), reduce odor – identify and evaluate status and potential of AD and LFGTE systems – Assess biomass resources (livestock manure, food processing waste, selected MSW, wastewater) – Establish AD and or LFGTE consortium or forum to coordinate, plan and evaluate AD and LFGTE	Program) Competitive Negotiation Solicitation : Develop and demonstrate advanced energy conversion options for biogas and landfill gas with low emissions Sole Source: ➢ Assessment of marketplace, economics and needs, strategic value to electricity grid	($ TBD) Competitive Negotiation Solicitation : Develop and demonstrate flexible microturbines using landfill gas and biogas from anaerobic digestion of livestock manure FlexEnergy International Inc ($984k) Sole Source: ➢ Strategic value Analysis ($ TBD)
2. **Near Term (2003/2004)** **b. Anaerobic Digestion and LFGTE**	Emerging competitive: – Costs still too high to be competitive in open market – Not dispatchable and need for reliable operation – Lack of grid integration – Lack of non energy revenue streams – High emissions (NOx, Sulfur oxides, formation of dioxin and furans)	Increase competitiveness in deregulated marketplace by developing techniques or processes that: – Select feedstock from the results of resource assessment (livestock manure, food processing waste, selected MSW, wastewater) – Continue/or establish AD and or LFGTE consortium/forum to coordinate, plan and evaluate AD and LFGTE – reduce costs and co-produce value added products – increase CH4 yield	Competitive RFP: ➢ Develop and demonstrate anaerobic digestion and LFGTE that reduces costs and lower emissions ➢ Develop and demonstrate distributed generation with co-production of value added products	2. **Near Term** **b. Anaerobic Digestion and LFGTE** **Proposed** ➢ Demos of systems -High eff. energy conversion /distributed gen (bioreactor, fuel cells and microturbines) – continue demo of Flexmicroturbine – gather performance data -Development of value added products -Lower emissions

Table 8: Biomass RD&D Needs and Approaches				
Timeframe /SubArea	***Issues***	***Focus***	***Funding Mechanisms***	***Funding Amount***
		and efficiency of conversion – develop distributed generation applications of AD and LFGTE – Demonstrate advanced energy conversion options and fuel cleaning and separation (fuel cells, microturbines)		($ 3 million)
3. **Mid Term (2007/2008)** **b. Anaerobic Digestion and LFGTE**	Cost effectiveness and affordability issues: – Need to lower costs – Lack of performance data (technical and economic performance) – Need for reliable and flexible grid interconnection	Continue developmentncrease competitiveness and environmental acceptability: • Lower costs • Increase CH4 yield and efficiencies • Improve process stability • Improve waste utilization (food and agricultural wastes, sewage sludges, MSW, etc)	Competitive RFP: Continue the development of the following: ➢ Development of lower cost LGR/biogas systems ➢ High efficiency energy conversion systems for LGR/biogas systems ➢ Development of LGR/biogas systems with value added products ➢ Develop and demonstrate low cost emission control technologies	**Mid Term (2007)** **b. Anaerobic Digestion and LFGTE** ➢ Development of lower cost LGR/biogas systems ➢ High efficiency energy conversion systems for LGR/biogas systems ➢ Development of LGR/biogas systems with value added products ➢ Develop and demonstrate low cost emission control technologies
4. **Long Term (2011/2012)** **b. Anaerobic Digestion and LFGTE**	Developmental Issues: • High costs • Lack of performance data	Demonstrate performance and economics of cost competitive systems : • Advanced systems- lower cost, high efficiency and co-produce value added products	Competitive RFP: Demonstrate performance and economics of • Advanced systems - lower cost, high efficiency and co-produce value added products • Biogas/LFGTE – fuel	**Long Term (2011)** **b. Anaerobic Digestion and LFGTE** • Advanced systems - lower cost, high efficiency and co-produce

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Table 8: Biomass RD&D Needs and Approaches

Timeframe /SubArea	*Issues*	*Focus*	*Funding Mechanisms*	*Funding Amount*
		• Biogas – fuel cell application • Biogas – microturbine application	cell application • Biogas – microturbine application	value added products • Biogas/LFGTE – fuel cell application • Biogas – microturbine application
1. Existing **a. Thermal gasification**	Not Competitive: – High Costs – High fuel costs – Lack of understanding of the potential of thermal gasification for electricity generation – Lack of understanding of marketplace needs and economics in a deregulated environment – Lack of understanding of strategic value of biomass thermal gasification in the grid – Lack of reliability and dispatchability data – Lack of non electricity revenue streams	Increase competitiveness in deregulated marketplace by developing techniques or processes that: – reduce costs (capital and O&M costs) – reduce fuel costs – increase efficiency – increase dispatchability – increase understanding of marketplace needs and economics – Perform strategic value analysis of biomass in the grid develop value added products	Competitive RFP solicitation: • High costs: ➢ GE-EER PIER 2 coupled gasification combustion to lower emissions and reduce costs using low value residues Competitive Negotiation Solicitation: • Distributed gen ➢ Community Power Corporation – develop small modular gasifier/engine system for combined power and heat application ➢ FlexEnergy International Inc – producer gas application of flexible microturbine Tech Assistance: ➢ Updated assessment of facilities, marketplace economics and needs Sole Source: ➢ Strategic value database and GIS of biomass power **conversion facilities (i.e., biomass power**	**1. Existing** **a. Thermal gasification** GE-EER PIER 2 $982k Competitive Negotiation Solicitation: Community Power Corp: $ 645,824 FlexEnergy International Inc Gasifier/Flexmicroturbine demo– (in $984k) Tech Asst EPRI membership Market and benefit assessment ($?) Sole Source: Strategic Value analysis ($ TBD)

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Table 8: Biomass RD&D Needs and Approaches				
Timeframe /SubArea	***Issues***	***Focus***	***Funding Mechanisms***	***Funding Amount***
			plants, power & co-ethanol production, anaerobic digestion & landfill gas recovery systems) in distributed generation setting	
2. **Near Term (2003/2004)** **b. Thermal Gasification**	Not competitive: – High costs – Low efficiencies – Unproven performance and economics	Development of competitive thermal gasification systems: – Develop and demonstrate small scale systems that can fill niche markets. – Evaluate biorefinery co-production of power, chemicals, and other value added products – Begin development of higher efficiency systems capable of firing advanced conversion systems (fuel cells, microturbines)	Various: Competitive RFP: ➢ Demonstrations of small scale gasification/energy conversion systems to meet niche markets Cooperative agmt: Development of higher efficiency, lower cost gasification and energy conversion systems	2. **Near Term** **b. Thermal Gasification** **Proposed** ➢ Demo. of small and distributed application: Develop high eff., low cost systems
3. Mid Term (2007/2008) **c. Thermal Gasification**	Not competitive: – High costs – Low efficiencies – Unproven performance and economics	Continue development of higher efficiency, lower cost gasification and energy conversion systems: • Demonstrate performance of coupled gasification combustion to improve eff, lower costs and emissions • gasification – fuel cell application • gasification-microturbine application	Competitive RFP: Continue development of higher efficiency, lower cost gasification and energy conversion systems: • coupled gasification combustion • gasification – fuel cell application • gasification-microturbine application	**3.Mid Term (2007)** **c. Thermal Gasification** Development of higher efficiency, lower cost gasification and energy conversion systems: • coupled gasification combustion • gasification – fuel cell application • gasification-microturbine application

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Table 8: Biomass RD&D Needs and Approaches				
Timeframe /SubArea	***Issues***	***Focus***	***Funding Mechanisms***	***Funding Amount***
4. Long Term (2011/2012) **c. Thermal Gasification**	Not competitive: – High costs – Low efficiencies – Unproven performance and economics	Demonstrate performance and economics of: • Improved gasification and energy conversion systems (low cost and higher efficiencies) • gasification – fuel cell application • gasification-microturbine application	Collaborative Agreement: • Improved gasification and energy conversion systems (low cost and higher efficiencies) • gasification – fuel cell application • gasification-microturbine application	**4. Long Term (2011)** b. **Thermal Gasification** Improved gasification and energy conversion systems (low cost and higher efficiencies) • gasification – fuel cell application • gasification-microturbine application

TBD – means To Be Determined

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A. Near-Term Outlook (2003/2004)

In 1999, biomass energy conversion technologies contributed a total of about 900 MW of operating capacity in California. Approximately 600 MW of this operating capacity comes from 29 direct combustion facilities employing fluidized bed or spreader stoker technologies. About 200 MW comes from fifty-one LFGTE recovery systems, over 90 MW comes from MSW and digester gas. Only 340 kW comes from anaerobic digestion of livestock manure. The base cost of electricity (COE) for these existing facilities falls between $.06 to $.12 per kWh (as shown in Section 4 above).

There has been an increased demand or lack of supply for California electric generating capacity recently. All of these operating facilities are expected to operate with the financial incentive support being provided under Renewables Trust Account and Agricultural Biomass to Energy Grant Program. The 10-year extension of Renewable Trust Account may help the idle direct combustion facilities to restart and provide additional capacity of about 128 MW.

In the near term, the biomass interagency working group and or the biomass consortium together with California Energy Commission's PIER Program shall actively sought for coordinated solutions impeding the development of biomass energy conversions. Coordination in RD&D activities, policy formulation and project implementation will start aggressively to help meet the electricity demand in the state.

It is envisaged that by the end of 2002 (or early 2003), electricity generation using biomass will emerge at $.045/kWh to $.06/kWh range depending on the types of biomass energy conversion pathways (Figures 18 and 19) with total generation of about 1000 MW. It may be expected that distributed generation technologies will start to be developed in the near term using biomass fuels (including solid biomass and biomass derived fuels such as landfill gas and biogas). These distributed generation technologies will help prevent air pollution emissions associated with open field burning of agricultural residues, provide alternatives to landfill disposal of urban wood wastes, and provide jobs and taxes in the more economically hard hit rural areas of California. Consequently, the proposed RD&D work also provides public benefits to a number of California electricity customers located in rural or forested areas of the state. However, to be sustainable in the near term and to increase the competitiveness of existing technologies and help meet the demand of added capacity, RD&D work will start and focus on techniques or processes as described below.

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For direct combustion:
- Investigating market place needs and economics
- Assessing resource potential and availability (i.e., forest thinnings)
- Reducing feedstock costs (harvesting, collection and processing)
- Improving reliability and dispatchability of existing technologies by developing hybrids such as co-firing of biomass with natural gas
- Developing small scale modular biomass systems for distributed generation applications
- Developing co-production of value-added products such as ethanol and other chemicals
- Reducing costs (capital, O&M)
- Reducing biomass fuel costs (harvesting, collection, processing and transportation)
- Reducing emissions (NOx)
- Improving efficiency

By the end of 2003-2004, the total installed capacity from direct combustion facilities (mainly distributed generation) will be 750 MW as a result of the R&D efforts.

For thermal gasification:
- Investigating potential opportunities, market place needs and economics (for small scale and large scale such as IGCC)
- Assessing resource potential and availability (i.e., forest thinnings)
- Reducing feedstock costs (harvesting, collection and processing)
- Improving reliability and dispatchability of existing technologies by developing hybrids such as co-firing of biomass with natural gas

- Developing coupled gasification/combustion system that will reduce emissions (NOx) and costs
- Developing distributed generation technologies such as small scale thermal gasification power system
- Developing co-production of value-added products
- Reducing costs (capital, O&M)
- Reducing fuel costs
- Improving efficiency

For LFGTE and anaerobic digestion:
- Investigating potential opportunities, benefits, interconnection in California electricity, market place needs and economics
- Assessing resource potential and availability (livestock manure, food processing waste, selected MSW, sludge and waste water)
- Reducing costs (capital, O&M)
- Reducing fuel costs
- Reducing emissions (NOx)
- Developing distributed generation applications
- Developing co-production of value-added products (fertilizer)
- Improving CH_4 recovery and efficiency

Fifty-one landfill gas to energy and four anaerobic digestion facilities of livestock manure are currently installed in California, generating slightly over 200 MW. Employing the above RD&D work will help support the sustainability and affordability of existing LFGTE and anaerobic digestion technologies from MSW and other wastes (livestock manure, food processing waste, sludge, and waste water). About 100 MW and 150 MW of LFGTE and anaerobic digestion/MSW facilities, respectively, would be added at the end of 2002 and or at the beginning of 2003.

For fermentation:
- Investigating potential opportunities, market place needs and economics of integrated co-production of power, ethanol and other value-added products
- Assessing resource potential and availability (i.e., forest thinnings, urban waste, ag residues, orchard prunings)
- Reducing feedstock costs (harvesting, collection and processing)
- Developing co-location of biomass to ethanol to existing biomass power plants or co-production of value-added products (ethanol and other chemicals)
  -Accelerated Lignin Tests for Biomass Power Plants
  -Use of Mixed Residues and starchy and sugar-based Biomass to Ethanol
  -Biomass Gasification/Fermentation
- Reducing costs (capital, O&M)
- Reducing fuel costs

One of the favorable options in the existing technologies is to link the biomass power plants with biomass-to-ethanol hosts and produce other value-added products. By the end of 2002, construction of 1-2 co-located biomass to ethanol plants should have started. This co-location option provides the biomass power facility one opportunity to increase its revenue from the sale of steam and electricity, and to spread its operating and fixed capital costs or a wider base of operations. On the other hand, the ethanol facility has: (1) access to cheaper steam and electricity than could be obtained otherwise; (2) access to infrastructure and wood handling operations; and (3) a nearby customer for lignin. If successful, this RD&D work will benefit California's biomass energy industry by helping ensure sustainability of the existing direct combustion facilities. It is expected that the co-located biomass to ethanol facility will help the associated biomass energy facility reduce its cost of electricity by at 1.5 cents/kWh and co-produce other value-added products.

B. Mid-Term Outlook (2007/2008)

The midterm PIER efforts for biomass will build on previous efforts. By the end of 2007, biomass to electricity generation technologies capable of generating electricity at \$.03/kWh to \$.045/kWh level (Figures 18 and 19) will be emerging in California generation marketplace with total capacity of about 1250 MW. R&D efforts to increase competitiveness in deregulated marketplace will continue as follows.

For direct combustion:

- Demonstrate and prove performance of biomass and natural gas cofiring and/or hybrid configurations
- Demonstrate and prove performance of distributed generation application
- Develop and demonstrate the co-production of electricity, ethanol and other value added products (biorefinery)
- Demonstrate lowering costs and improvement in efficiency
- Demonstrate reduction in NOx emissions
- Developing new and advanced combustion systems

Due to these RD&D efforts, by the end of 2007, the direct combustion facilities are expected to increase to about 1000 MW. The expected increase are a confluence of different factors; lower costs, increase efficiencies, generate revenues in addition to those resulting from electricity sales, and increase use of waste materials. These factors allow some of the idle facilities (~70 MW) to operate in a competitive mode. The expected increase in capacity also includes the development and demonstration of small-scale or distributed generation (i.e., < 5 MW) facilities. The small-scale power plants will have greater flexibility and dispatchability and can be constructed and sited much more quickly. Growth in small scale facilities (~50 to 80 MW) will be primarily based on a demand for distributed generation resources that defer more expensive T&D expansions or upgrades in areas that also have biomass waste disposal issues.

For thermal gasification:

Demonstrate coupled gasification combustion system to lower NOx emission and reduce costs

Demonstrate and prove performance of distributed generation application of thermal gasification using microturbines

Demonstrate thermal gasification for fuel cell application

Developing improved efficiency for thermal gasification with improved hot gas clean up such as IGCC (niche market)

For LFGTE and anaerobic digestion:

Develop, demonstrate and prove performance of increase CH_4 recovery and improved efficiency

Demonstrate and prove performance of distributed generation application of LFGTE and anaerobic digestion using microturbines (low costs and low NOx emissions)

Develop and demonstrate LFGTE and AD for fuel cell applications (low costs and low NOx emissions)

An emergence of new LFGTE technologies (controlled landfills) is estimated to occur by 2007. Controlled LFGTE technologies will develop in response to requirements that municipalities recycle fifty percent of the municipal solid waste stream by the year 2000. These LFGTE may include solid "composting" products from aerobic processes, solid "soil amendment" products from anaerobic processes, and electricity generation from combustion of the landfill gas. In addition, these controlled landfills will be tied to emergence of more efficient and clean energy conversion systems, such as microturbines and fuel cells. Where landfills are used as controlled reactor, advancements will occur in response to the desire to obtain better decomposition of landfilled biomass materials, and to make landfill gas recovery and utilization more cost effective. Consequently, improvements in using landfills as the reactor will focus on methods to control the biochemical processes occurring in landfills, reduce decomposition times, achieve better landfill gas recovery rates, and prevent ground water pollution. Due to the regulatory drivers, and the advancements in technology, over 100 MW of new LFGTE capacity are expected to appear in California by 2007.

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Similarly, improvements in anaerobic digestion gas technology will be based on increasing concerns over ground water contamination, odor problem and associated with current land disposal methods of animal wastes, increasing pressure to capture global climate change gases (primarily methane), and the commensurately higher costs of compliance. In response, industry will develop lower cost methods for treatment, capture and conversion of the resulting "biogas," while simultaneously developing new value added products beyond electricity generation. It is anticipated to be a modest growth in digester gas to energy projects representing about 50 MW of new capacity by 2007.

For fermentation:

Demonstration and prove performance of co-located biomass facilities:

Develop and demonstrate biomass gasification and fermentation

Demonstrate ethanol fuel for fuel cell application

If the biochemical pathways leading to ethanol from synthesis gas are fully understood, the optimal conditions for cultivation of the microorganism are fully worked out, and a reliable and economical process linking gasification, fermentation, and ethanol separation are in place, then a demonstration of BGF may be possible. The technology for the conversion of sugar based and starchy crops to ethanol is very well understood, and many facilities using this technology are already in operation. Therefore, it is envisioned that such a facility will most likely be in place in California, and that this facility will use as its feedstock starchy crops grown in California. The facility may also be configured to handle a variety of feedstocks, namely high glucose content food and beverage wastes, sulfite liquors from pulp and paper operations, and sugar beets. By 2007, it is hoped that it will implement 2 to 3 co-located biomass to ethanol facilities. The pace of co-location will be accelerated to handle the growth in demand for ethanol.

C. Long-Term Outlook (2011/2012)

By the end of 2011 (and or the beginning of 2012), the total electricity generation capacity from biomass is envisaged to be at 1500 MW. The COE ranges from \$.025/kWh to \$.035/kWh depending on the energy conversion pathways.

For direct combustion:

Demonstrate and prove performance of advanced small scale and larger scale direct combustion systems

By 2011, small scale or distributed generation of direct combustion technologies will have fully emerged. Likewise, there will be an emergence of the larger scale biomass facilities. Development of small and large-scale plants will be a response to localized demand for voltage support, and occur in rural/agricultural areas, urban interfaces or border on heavily forested areas. In either location, the larger facilities will likely be sited close to existing agricultural chemical processing facilities that can serve as a consumer of value added products generated by the facilities. The larger scale systems should be cost competitive in the deregulated electricity marketplace and capable of handling a variety of biomass materials. In addition, provide high strategic value to the grid, generate high value products (such as ethanol) in addition to electricity, and receive economic gain for contributing non-energy benefits to the community. Perhaps small-scale systems will be economically competitive in the open market, but will be cost effective in niche markets, primarily in the industrial and agricultural sector. For both small and larger scale or classes of direct combustion technology, the systems will provide a cost effective alternative to landfill disposal of woody type wastes (e.g., urban, agricultural and forestry residues), and will have air emissions on par with equivalently sized natural gas fired systems.

Overall, it is expected that there will be a growth of approximately 50 to 100 MW of new small-scale facilities and 100 to 150 MW of new and larger scale facilities in California; bringing the total capacity of direct combustion biomass power plants to over 1250 MW by 2011.

For thermal gasification:

Demonstrate and prove performance of small scale thermal gasification systems
-distributed generation application (microturbines, Stirling engines and fuel cell)

Demonstrate larger scale integrated gasification combined cycle IGCC

Small scale thermal gasification systems firing gas turbines or other prime movers will also have fully emerged as distributed generation resources in California. Larger scale IGCC will start to be demonstrated in California. They should have efficiencies comparable to competing fossil fired generation facilities, be capable of using a variety of woody wastes as fuels, be rapidly dispatched, and provide high power quality to the grid.

For LFGTE and anaerobic digestion:

Demonstrate and prove performance of fuel cells, advanced microturbines, or Stirling Engines

A variety of LFGTE and anaerobic digestion facilities will have been developed by 2011/2012. This will including fuel cells, advanced micro-turbines and Stirling engines. Commercially available anaerobic digestion systems will provide a cost effective way to dispose of animal wastes, while simultaneously providing electricity and thermal energy for use on-site, as well as value added products such as soil amendments and fertilizers. Controlled reactors for landfill gas to energy systems will be fully commercial. Due to revenues generated from receipt of organic wastes and production of valuable

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byproducts, in combination with high efficiency energy conversion systems, electricity generated from landfill gas to energy facilities is expected to be among the lowest cost electricity in California's grid.

For fermentation:

Demonstration and prove performance of co-located biomass facilities:

Develop and demonstrate biomass gasification and fermentation

Demonstrate ethanol fuel for fuel cell application
As these facilities will have to produce other specialty, low volume, high value added chemicals in order to be profitable. At this stage, the 'biorefinery' concept will be implemented, and ethanol, electricity, and other chemicals will be produced at one facility. Finally, over the longer term, milder enzyme based technologies will be developed and hopefully may be used to produce fuels and chemicals.

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VII. Biomass PIER Projects, Budget and Plans

To date, the Energy Commission has provided nearly $5 million in funding to biomass energy RD&D projects under PIER Renewables. Table 9 provides a summary listing of biomass projects funded under PIER by technology type. Table 9 also shows the R&D focus based on the RD&D plan described in Section 6.

Table 9. Biomass RD&D Projects Being Funded Under PIER

Technology Type	***R&D Focus***	***Company Name***	***Project Title***	***Amount Awarded***
Biomass direct combustion	Improve reliability and dispatchability Reduce Emissions	Gas Research Institute	Natural Gas Cofiring in Biomass Fueled Boilers	$655,702
Gasification/ combustion	Reduce emissions and costs	Energy and Environmental Research Corporation	Utilization of Waste Renewable Fuels in Boilers with Minimization of Pollutant Emissions	$981,952
Colocation of biomass ethanol direct combustion	Co-produce value-added products	Collins Pine Company	Collins Pine Company/BCI Cogeneration Project	$1,148,961
Gasification LFGTE Anaerobic digestion	Distributed generation Improve reliability and dispatchability Reduce cost Reduce emissions	FlexEnergy International	The Flex-microturbine uniquely adapted to low-pressure biomass gases	$983,653
Gasification	Distributed generation	Community Power Corporation	Small Modular Biopower of Bio-Breeder Project	$645,827
Combustion	Reduce costs	Ogden Power Pacific	Accelerated Lignin Tests for Biomass Power Plants	$500,000
All	Market and	EPRI		Through

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technologies	Benefits Assessments			EPRI membership
Hybrid	Improve reliability and dispatchability	EPRI	Feasibility Study of Biomass/Natural Gas (IGCC)	$50k
All technologies	Assess strategic value		Strategic Value Analysis	

Plan for Fiscal Year 2000/2001

RD&D activities will focus on prioritizing the biomass RD&D targeted areas of research and finalize the RD&D plan.

Continue to perform market assessment and a strategic value analysis. The allocated funding for the market assessment and strategic value analysis is estimated at $60k and $30k, respectively.

Finalize competitive negotiation solicitation for small modular biomass. The budget allocated for this solicitation is $1.6 million.

Sole source solicitation for accelerated lignin tests for biomass power plants. The budget for this project is $500k.

During the third quarter, competitive solicitation will commence to help make existing biomass energy conversion facilities more cost competitive and/or affordable. This solicitation will be included in the programmatic solicitation for all renewables. The budget for biomass is unknown, however, the proposed funding level for the programmatic solicitation is about $18 million.

For fourth quarter, targeted areas of research will commence through a competitive solicitation process for the development and demonstration of anaerobic digestion and landfill to gas energy projects (or biogas technology conversion systems). The proposed budget for this solicitation is about $3 million.

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Plan for Fiscal Year 2001/2002

For Fiscal year 2001/2002, it is proposed to have a competitive solicitation for demonstration of distributed generation application of biomass energy conversion systems such as thermal gasification systems and other advanced distributed generation systems using biomass and biomass-derived fuels. The proposed budget is about $4 million.

Plan for Fiscal Year 2002/2003

In this fiscal year, targeted area of research will commence through a targeted solicitation for biogas systems or competitive negotiation solicitation for the demonstration of co-located biomass to ethanol and co-produce other value added products. The proposed budget is $5-7 million.

For Fiscal Year 2003/2004

For this fiscal year, it is envisaged to initiate a competitive solicitation for advanced and integrated biomass energy conversion systems (i.e., coupled gasification and combustion, integrated gasification systems, hybrids, biorefinery). Proposed funding for this solicitation is about $10 million.

For Fiscal Years 2005-2012

To be Determined.

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